**AAON,Inc.**

2425 South Yukon Ave · Tulsa, Oklahoma 74107-2728 · Ph. (918) 583-2266 Fax (918) 583-6094

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# Worksheet

AAONEcat32 Ver. 4.08 Beta

RL-075-3-0-AA04-000:A000-E00-JAZ-A0A-GA0ADBJ-00-00000000X

Tag: 3 West

Job Name: *Borders East Tower*
Job Number: *Job #2*
Worksheet For: *Borders Group Inc.*
Worksheet Date: *February 26, 2001*

| | Base Option | Description | List Price | Rep. Price | Cust. Price |
|---|---|---|---|---|---|
| R | Series | Roof Top Unit | | | |
| L | Generation | Eighth Generation | | | |
| 075 | Size | Seventy Five | | | |
| 3 | Voltage | 460V/3Ø/60Hz | [redacted] | [redacted] | [redacted] |
| 0 | Interior Protection | Standard | | | |
| A | Cooling Style | Draw Thru - R22 Dual Circuited Compressors | | | |
| A | Cooling Configuration | Air Cooled Cond w/ 4R Coil High CFM | | | |
| 0 | Cooling Coating | Std | | | |
| 4 | Cooling Stages | 4 Stage | | | |
| 0 | Heating Type | No Heat | | | |
| 0 | Heating Designation | No Heat | | | |
| 0 | Heating Stages | No Heat | | | |

| | Feature Option | Description | List Price | Rep. Price | Cust. Price |
|---|---|---|---|---|---|
| A | 1A.Outside Air Options | Economizer | [redacted] | [redacted] | [redacted] |
| 0 | 1B.RA Blower Configuration | Std (No return or exhaust blower) | | | |
| 0 | 1C.RA Blower | Std (No return or exhaust blower) | | | |
| 0 | 1D.RA Motor | Std (No Motor) | | | |
| E | 2.Outside Air Controls | DDC Econ Control | | | |
| 0 | 3.Discharge Location | Bottom Discharge | | | |
| 0 | 4.Return Location | Bottom Return | | | |
| J | 5A.SA Blower Configuration | 2 Blowers w/(Prem eff mtr) w/1-VFD | | | |
| A | 5B.SA Blower | Blower A (27" Diameter) | | | |
| Z | 5C.SA Motor | 20.0 hp (1760 rpm) | | | |
| A | 6A.Pre-Filter | 4" Pleated | | | |
| 0 | 6B.Final Filter | Std | | | |
| A | 6C.Filter Options | CFS Pre Filter | | | |
| G | 7.Refrigeration Controls | 5 MTDR On & Off + 115V Outlet Factory Wired | | | |
| A | 8.Refrigeration Options | Hot Gas Bypass Lead Stage [HGB] | | | |
| 0 | 9.Refrigeration Accessories | Std | | | |
| A | 10.Power Options | 225 Amps Power Switch | | | |
| D | 11.Safety options | R/A & S/A Smoke Detector | | | |
| B | 12.Controls | Phase & Brown Out Protection | | | |
| J | 13.Special Controls | Factory Installed DDC Controls by Others | | | |
| 0 | 14A.Pre-Heat Configuration | Std (No Preheat) | | | |
| 0 | 14B.Pre-Heat Sizing | Std (No Preheat) | | | |
| 0 | 15.Option Boxes | Std | | | |
| 0 | 16.Cabinet Options | Std | | | |
| 0 | 17.Cabinet Options | Std | | | |
| 0 | 18.Customer Code | Std | | | |
| 0 | 19.Code Options | Std ETL USA Listing | | | |
| 0 | 20.Unit Splits | Std (One Piece Unit) | | | |
| 0 | 21.Evap & Water Condenser | Std (No Evap or Water Condenser) | | | |
| 0 | 22.Blank | Std | | | |
| X | 23.Type | Special Price Authorization & Gray Paint | | | |
| | | Subtotal | [redacted] | [redacted] | [redacted] |
| | | Quantity | | | |
| | | Total | [redacted] | [redacted] | [redacted] |

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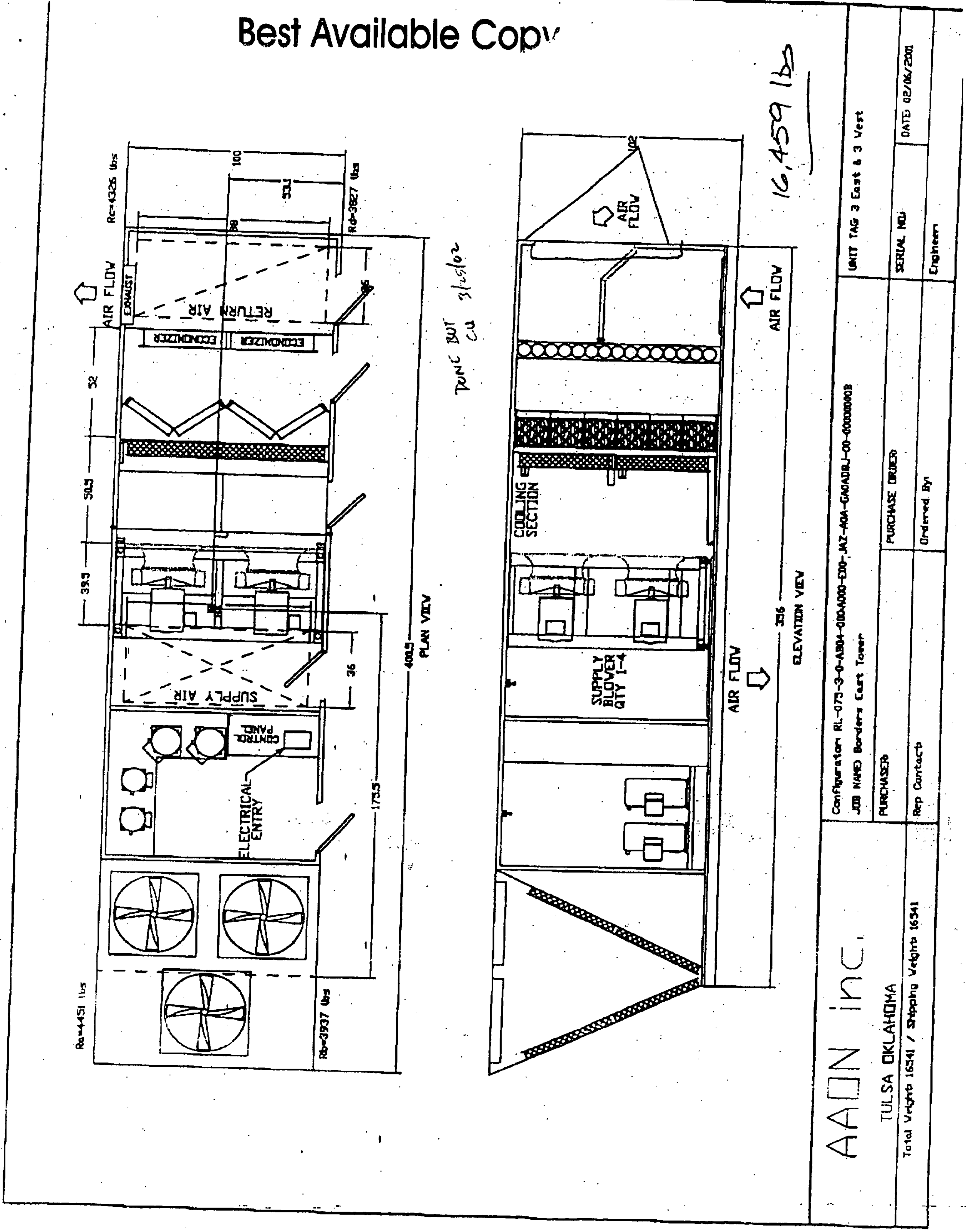

SHIP ON 1/8/99

**AAON, Inc.**
2425 S. Yukon • Tulsa, OK 74107 • Ph:(918) 583-2266 • Fax:(918) 583-6094

DATE: 9/15/98 PAGE ____ of ____ **Order Form**

SOLD TO:
BOVIS CONSTRUCTION CORP
PRINCETON FORRESTAL VILLAGE
100-200 VILLAGE BLVD.
PRINCETON, N.J. 08540

CUSTOMER P.O. No. ____ JOB No. ____
JOB NAME: THE COMMONS
CUSTOMER No. ____
SHOP ORDER No. 194639
AAON CONTACT: J. BARBERA
CUST. CONTACT: K. GARDINELL
REP. #1 757 REP. #2 ____

SHIP TO:
(WILL ADVISE)

SHIPPING INFORMATION
REQ. SHIP DATE: ____ HOLD FOR APPROVAL ☐ RELEASE TO PRODUCTION ☐
SHIP VIA: FRT ALLOWED
ALLOWED ☒ PPD & ADD ACTUAL ☐ COLLECT ☐
NOTIFY: RICK
48 HOURS BEFORE DELIVERY @ PHONE No.: 609/419-1380

MARKETING CODE: 90 SHIP ZONE: ____

| QTY | PART No. | DESCRIPTION | Unit Net Ea. | EXT. |
|---|---|---|---|---|
| 6 | | R(F)110-3-FO-1D1 : N\|6\|L\|J\|0\|D\|G\|0\|J\|ø\|1\|0\|0\|A\|X | [redacted] | |
| | | CFM ESP NOTE: (1) TAG# 1A, 2A, 3A, 4A, 1B & 2B | | |
| | | TAG RTU: (2) 46,500 CFM @ 2.75 ESP (3) SEE NOTES | | |
| | | (4) 7.5 HP VFD ON PROP EXHAUST | | |
| | | R( ) : ø | | |
| | | CFM ESP (5) WIRE ALL ANNALOGUE | | |
| | | TAG RTU: SIGNALS TO LVTB (6) LEAVE 12 INCH X | | |
| | | 12 INCH AREA IN CONTROL BOX FOR FIELD CONTROLLER | | |
| 2 | | R(F)130-3-FO-1D1 : N\|6\|L\|J\|0\|D\|G\|0\|J\|ø\|1\|0\|0\|A\|X | [redacted] | |
| | | CFM ESP NOTE: (1) TAG# 5A & 5B (2) 46,500 CFM | | |
| | | TAG RTU: @ 2.75 ESP (3) SEE NOTES (4) WIRE ALL | | |
| | | ANNALOGUE SIGNALS TO LVTB (5) LEAVE | | |
| | | R( ) : ø | | |
| | | CFM ESP 12 INCH X 12 INCH AREA IN CONTROL | | |
| | | TAG RTU: BOX FOR FIELD CONTROLLER | | |
| | | R( ) : ø | | |
| | | CFM ESP | | |
| | | TAG RTU: | | |
| 1,200 FT | | PU1980 | N/C | |

NOTE: (1) SPECIAL EVAP COILS (SEE 90A)
(2) PERFORATED LINERS IN SUPPLY AIR
(3) INSTALL CUSTOMER FURNISHED TEMP SENSORS - O/A - R/A - MIXED AIR
(4) PER NORM SHIP BY 1/8/98
(5) FURNISH & INSTALL DP SWITCH FOR SUPPLY FAN STATUS
(6) FURNISH & INSTALL ISOLATION

Multiplier .35
TOTAL NET (Rep. Cost) $ [redacted]
FREIGHT $ 16,000.00
COMMISSION $ [redacted]
TOTAL BILLING $ [redacted]

REP. CONTACT: ____
ORDERED BY: ____

1997

NO PO ON PO# RELAYS FOR CHL & HWC ...

CL 297

10/01/1998 08:12 7329810939 GIL BAR SALES PAGE 02

**AAON, Inc.**

**Estimating Worksheet**

Tulsa, Oklahoma • Ph: (918) 583-2266 • Fax: (918) 583-6094

DATE: REVISION 9/30/98 PAGE 2 of 9

**NOTE:** THIS WORKSHEET IS FOR ESTIMATING PURPOSES ONLY AND IS NOT INTENDED FOR ORDER PROCESSING.

| | MARK • RTU No. 1A... | | MARK • RTU No. 5A... | | MARK • RTU No. | | MARK • RTU No. | |
|---|---|---|---|---|---|---|---|---|
| **MODEL NUMBER** | | | | | | | | |
| SERIES | R F | | R F | | R | | R | |
| UNIT SIZE | 110 | | 120 | | | | | |
| VOLTAGE | 3 | | 3 | | | | | |
| COOLING | E O | | F O | | | | | |
| BASE UNIT PRICE | $ [redacted] | | $ [redacted] | | $ | | $ | |
| HEATING | 1 D 1 | | 1 D 1 | | | | | |
| HEATING PRICE | $ [redacted] | | $ [redacted] | | $ | | $ | |
| **FEATURE NUMBER** | OPTION | LIST PRICE | OPTION | LIST PRICE | OPTION | LIST PRICE | OPTION | LIST PRICE |
| 1 OUTSIDE AIR | N | [redacted] | N | [redacted] | | | | |
| 2 BLOWER MTR. | L | [redacted] | L | [redacted] | | | | |
| 3 FILTER OPT. | L | [redacted] | L | [redacted] | | | | |
| 4 REFRIG. CTL. | J | [redacted] | J | [redacted] | | | | |
| 5 REFRIG. OPT. | O | – | O | – | | | | |
| 6 POWER OPT. | H | [redacted] | H | [redacted] | | | | |
| 7 SAFETY OPT. | G | [redacted] | G | [redacted] | | | | |
| 8 CONTROL OPT. | A | – | A | – | | | | |
| 9 SPECIAL CTL. | J | – | J | – | | | | |
| 10 OPEN | Ø | – | Ø | | Ø | | Ø | |
| 11 CODE OPT. | O | – | O | | | | | |
| 12 CABINET OPT. | O | | O | | | | | |
| 13 SYSTEM PKG. | A | [redacted] | A | [redacted] | | | | |
| 14 TYPE | B | – | B | – | | | | |
| TOTAL UNIT LIST PRICE | $ [redacted] | | $ [redacted] | | $ | | $ | |
| CLASS / TYPE KD | $ | | $ | | $ | | $ | |
| SB | $ | | $ | | $ | | $ | |

**ACCESS** (ACCESSORIES)

| | RTU 1A... | RTU 5A... | |
|---|---|---|---|
| | 6/14 91.25 ϕ DX COIL | 6/14 91.25 ϕ DX COIL | INCL. |
| → | PERF LINERS-SUPPLY | PERF. LINER-SUPPLY | #3600 |
| | MOUNT DDC | MOUNT DDC | 1450 |
| | 49" SUPPLY FAN | — | 750 (RTU - 1A... ONLY) |
| | EXH. VFD - 7.5 HP | EXH. VFD - 7.5HP | 2750 |
| LIST PRICE EA | [redacted] | [redacted] | |
| NET EA. | .35 [redacted] | .36 [redacted] | |

98

8/18
7/9

AAON, INC.
2425 South Yukon
Tulsa, Oklahoma 74107
Phone: (918) 583-2266
Fax: (918) 583-6094

# AAON, INC.

# FAX

TO: Kevin Gabinelli
Gil-Bar

FROM: Natalie Neilson

DATE: 6-30-98

FAX NO: 732-981-0939

PAGES: 1

SUBJECT: RF-130 Special Pricing – SPA#89008

Kevin,

To provide the RF-130 with perforated liners on the supply section is $3,600 list add.
~~To provide the RF-130 with perforated liners on the return section is $3,100 list add.~~

I do not have the pricing for the entire unit, so I will have to research this and get back with you.

Also, I don't know what to tell you on the "Sharing ?" job, you really need to discuss this matter with Steve pagetter. Sorry!!!!

*This pricing is valid for use within 30 days of this transmission. Please send in a copy of this letter or the SPA number to expedite the process.*

Thank you,

Natalie Neilson
Ext. 293

BM03L5 AC AAON, INC. WIRING DIAGRAM ASSIGNMENT & VERIFICATION 01 Apr 2002 PAGE 1

REQUESTED BY ccox-eng /dev/pts/29

REQUISITION NUMBER: 256816

ORDER INFORMATION
CUSTOMER: FREY LUTZ CORPORATION
SHIP-TO : HARRISBURG, PA 17110
JOB NAME: FARM SHOW ARENA

LEAD DTE: 12/27/01 SHIP ON : 06/30/02

CONTACT : B. SMITH

| SEQ | PART NBR | QTY | DESCRIPTION | DISPOSITION |
|---|---|---|---|---|
| 001 | @ | 0 | RL-135-3-0-FZ0Q-344: A000E00KB2CP0D00A00J000GB00000X | --no-ENG |
| 002 | @ | 9 | RL-230-3-0-0F08-354: BGBEE00KEICP0DACB00J000GR00AA0X | EEfrnt 04/01/02 by CCOX-EN |
| 003 | @FREIGHT | 1 | | --no-ENG |
| 004 | @REP-780 | 1 | | --no-ENG |

Sales and Engineering text lines for entire order
----------------SALES HEADER INFO------
NOTE ON JOB SAYS "HOLD FOR APPROVAL" (WRITTEN BY JIM PARRO)
REVISED OPTION #15 FROM [0] TO [A] PER J. PARRO 1/4/02 DS
3/5 PER BRETT S.-SHIP APPROX. 6/30. JL
PER BUCK NYE SHIP UNITS END OF JUNE IF POSSIBLE!!!
-----------------ENG HEADER INFO-------
--------------SALES LINE ITEM # 001-----
1] 38000 CFM @ 1.5 ESP
2] SUPPLY FAN BACK DRAFT DAMPER
3] SPA #101255
4] TAG #1
--------------SALES LINE ITEM # 002-----
1] 42500 CFM @ 2.25 ESP
2] SUPPLY FAN BACK DRAFT DAMPER
3] RA FAN PITCH 40"
4] TAG #1 THRU 9
5] SPA #101255
6] 8 ROW DX COILS
7] (4) COPELAND SCREW COMPRESSORS
8] STAINLESS STEEL CONDENSER FAN MOTOR SHAFT
9] 14 GA. BASE SHEETS
10] BURGLAR BARS ON 3" CENTERS
11] FACTORY INSTALL CUSTOMER PROVIDED CONTROLS
12] MAKE-UP WATER BACKFLOW PREVENTER

RL230
Cooling (4 screw / Evap cooled cond)
GAS Heat (12 stg (10 Tubes))
2 Power exhaust w/ 2 VFDS
DDC Eco —
2 Supply Fans w/ 2 VFDS
Marine Lights.

CL 300

# AAON,Inc. Worksheet

2425 South Yukon Ave - Tulsa, Oklahoma 74107-2728 - Ph. (918) 583-2266 Fax (918) 583-6094

AAONEcat32 Ver. 4.08 Beta

1A 1B 1C 1D 2 3 4 5A 5B 5C 6A 6B 6C 7 8 9 10 11 12 13 14A 14B 15 16 17 18 19 20 21 22 23

RL-075-8-0-0B04-000:BCBD-DAF-EAE-000-G00B000-00-00000000B

Tag: RTU# 1

| | | | |
|---|---|---|---|
| Job Name: | *HARRISON HILLS* | Worksheet For: | *Jacco Associates* |
| Job Number: | *Job #1* | Worksheet Date: | *February 26, 2002* |

| | Base Option | Description | List Price | Rep. Price | Cust. Price |
|---|---|---|---|---|---|
| R | Series | Roof Top Unit | | | |
| L | Generation | Eighth Generation | | | |
| 075 | Size | Seventy Five | | | |
| 8 | Voltage | 208V/3Ø/60Hz | [redacted] | [redacted] | [redacted] |
| 0 | Interior Protection | Standard | [redacted] | [redacted] | [redacted] |
| 0 | Cooling Style | Blow Thru - R22 Dual Circuited Compressors | [redacted] | [redacted] | [redacted] |
| B | Cooling Configuration | Air Cooled Cond w/ 6R Coil High CFM | [redacted] | [redacted] | [redacted] |
| 0 | Cooling Coating | Std | [redacted] | [redacted] | [redacted] |
| 4 | Cooling Stages | 4 Stage | [redacted] | [redacted] | [redacted] |
| 0 | Heating Type | No Heat | [redacted] | [redacted] | [redacted] |
| 0 | Heating Designation | No Heat | [redacted] | [redacted] | [redacted] |
| 0 | Heating Stages | No Heat | [redacted] | [redacted] | [redacted] |

| | Feature Option | Description | List Price | Rep. Price | Cust. Price |
|---|---|---|---|---|---|
| B | 1A.Outside Air Options | Power Exhaust | [redacted] | [redacted] | [redacted] |
| C | 1B.RA Blower Configuration | 1 Blower (Prem eff mtr) | [redacted] | [redacted] | [redacted] |
| B | 1C.RA Blower | Blower B (42" Dia 9 Blade) | [redacted] | [redacted] | [redacted] |
| D | 1D.RA Motor | 3.0 hp (1170 rpm) | [redacted] | [redacted] | [redacted] |
| D | 2.Outside Air Controls | Full Mod Enthalpy Econ | [redacted] | [redacted] | [redacted] |
| A | 3.Discharge Location | Front Discharge | [redacted] | [redacted] | [redacted] |
| F | 4.Return Location | Front Return High CFM (w/ erc or pwr ex) | [redacted] | [redacted] | [redacted] |
| E | 5A.SA Blower Configuration | 2 Blowers w/(Prem eff mtr) | [redacted] | [redacted] | [redacted] |
| A | 5B.SA Blower | Blower A (27" Diameter) | [redacted] | [redacted] | [redacted] |
| E | 5C.SA Motor | 5.0 hp (1170 rpm) | [redacted] | [redacted] | [redacted] |
| 0 | 6A.Pre-Filter | 2" Pleated | [redacted] | [redacted] | [redacted] |
| 0 | 6B.Final Filter | Std | [redacted] | [redacted] | [redacted] |
| 0 | 6C.Filter Options | Std | [redacted] | [redacted] | [redacted] |
| G | 7.Refrigeration Controls | 5 MTDR On & Off + 115V Outlet Factory Wired | [redacted] | [redacted] | [redacted] |
| 0 | 8.Refrigeration Options | Std | [redacted] | [redacted] | [redacted] |
| 0 | 9.Refrigeration Accessories | Std | [redacted] | [redacted] | [redacted] |
| B | 10.Power Options | 400 Amps Power Switch | [redacted] | [redacted] | [redacted] |
| 0 | 11.Safety options | Std | [redacted] | [redacted] | [redacted] |
| 0 | 12.Controls | Std | [redacted] | [redacted] | [redacted] |
| 0 | 13.Special Controls | Std | [redacted] | [redacted] | [redacted] |
| 0 | 14A.Pre-Heat Configuration | Std (No Preheat) | [redacted] | [redacted] | [redacted] |
| 0 | 14B.Pre-Heat Sizing | Std (No Preheat) | [redacted] | [redacted] | [redacted] |
| 0 | 15.Option Boxes | Std | [redacted] | [redacted] | [redacted] |
| 0 | 16.Cabinet Options | Std | [redacted] | [redacted] | [redacted] |
| 0 | 17.Cabinet Options | Std | [redacted] | [redacted] | [redacted] |
| 0 | 18.Customer Code | Std | [redacted] | [redacted] | [redacted] |
| 0 | 19.Code Options | Std ETL USA Listing | [redacted] | [redacted] | [redacted] |
| 0 | 20.Unit Splits | Std (One Piece Unit) | [redacted] | [redacted] | [redacted] |
| 0 | 21.Evap & Water Condenser | Std (No Evap or Water Condenser) | [redacted] | [redacted] | [redacted] |
| 0 | 22.Blank | Std | [redacted] | [redacted] | [redacted] |
| B | 23.Type | Std (Includes 'Gray Paint') | [redacted] | [redacted] | [redacted] |
| | | **Subtotal** | [redacted] | [redacted] | [redacted] |
| | | **Quantity** | [redacted] | [redacted] | [redacted] |
| | | **Total** | [redacted] | [redacted] | [redacted] |

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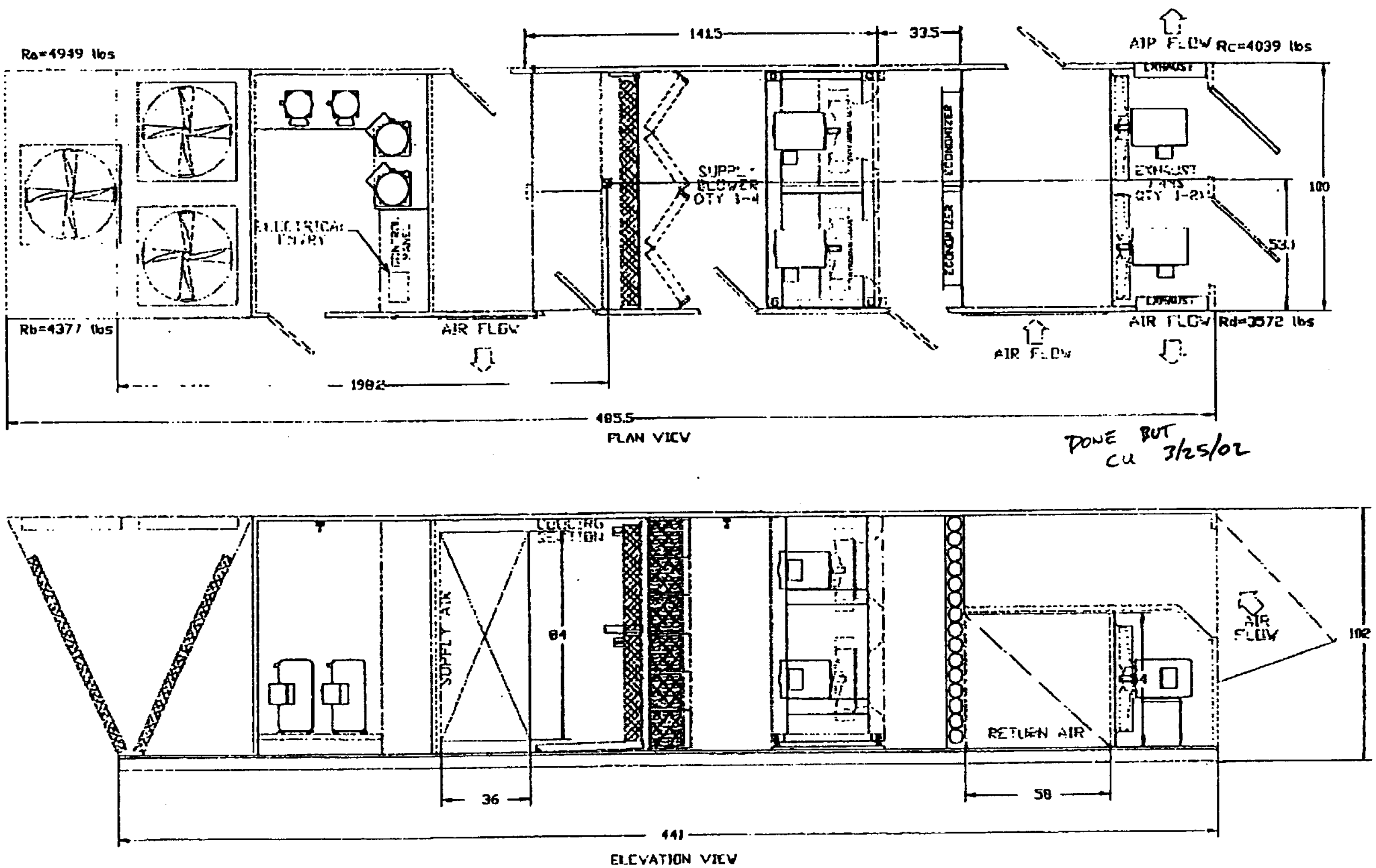


DONE BUT CU 3/25/02

| | | | | |
|---|---|---|---|---|
| AAON inc. TULSA OKLAHOMA | Configurator: RL-075-8-0-0B04-000-BCBD-DAF-EAE-000-600B000-00-00000000B<br>JOB NAME: HARRISON HILLS | | UNIT TAG: RTU# 1 | |
| | PURCHASER: Jacco Associates | PURCHASE ORDER: 02009/wdb | SERIAL NO.: | DATE: 02/26/2002 |
| Total Weight: 16937 / Shipping Weight: 16937 | Rep Contact: | Ordered By: W.D Brown | Engineer: | |

CL 302

## RL FEATURE MASTER—FEATURE NUMBER
UPDATED 10/17/01

### 1st FEATURE—RETURN/OUTSIDE AIR OPTIONS

| A FEATURE—OUTSIDE AIR SECTION | B FEATURE—R/A BLOWER CONFIG. | C FEATURE—R/A BLOWER | D FEATURE—R/A MOTOR |
|---|---|---|---|
| 0=Std - Manual Outside Air | 0=Std (No return or exhaust blower) | 0=Std (No return or exhaust blower) | 0=Std (No return or exhaust blower) |
| A=Economizer | A=1 Blower (Standard efficiency motor) | A=Blower A (36" Dia 6 Blade) | A=.75 hp (1170 rpm) [illegible] |
| B=Power Exhaust | B=2 Blowers (Standard efficiency motor) | B=Blower B (42" Dia 8 Blade) | B=1.0 hp (1170 rpm) [illegible] |
| C=Power Return | C=1 Blower (Premium efficiency motor) | C=Blower C (42" Dia 12 Blade) | C=2.0 hp (1170 rpm) [illegible] |
| D=Heat Wheel Small (T) (one 74 inch wheel) | D=2 Blowers (Premium efficiency motor) | D=Blower D (48" Dia 16 Blade) | D=3.0 hp (1170 rpm) |
| E=Heat Wheel Medium (T) (one 81 inch wheel) | E=Option C w/ VFD | | E=5.0 hp (1170 rpm) |
| F=Heat Wheel Large (T) (two 74 inch wheels) | F=Option D w/ two motors on one VFD | | F=7.5 hp (1170 rpm) |
| G=Heat Wheel Extra Large (T)(two 81 inch wheels)[2] | G=Option D w/ two motors on two VFD's | | G=10 hp (1170 rpm) |
| H=Heat Wheel Small (S) (one 74 inch wheel)[1] | | | H=15 hp (1170 rpm) |
| J=Heat Wheel Medium (S) (one 81 inch wheel)[1] | | | J=20 hp (1170 rpm) |
| K=Heat Wheel Large (S) (two 74 inch wheels)[1] | | | K=25 hp (1170 rpm) |
| L=Heat Wheel Extra Large (S)(two 81 inch wheels)[1,2] | | | L=30 hp (1170 rpm) |
| M=100% Outside Air (Non-Motorized-No R/A) | | | M=40 hp (1170 rpm) |
| N=Motorized O/A—2 Position (0-50%) | | | N=50 hp (1170 rpm) |
| P=Motorized O/A—2 Position (0-100%) No R/A | | | P=60 hp (1170 rpm) [illegible] |
| | | | Q=.75 hp (1760 rpm) [illegible] |
| | | | R=1.0 hp (1760 rpm) [illegible] |
| Notes: | | | S=2.0 hp (1760 rpm) [illegible] |
| [1] Contact Factory for SPA on Sensible Heat Wheels | | | T=3.0 hp (1760 rpm) |
| [2] D and E Cabinet Only | | | U=5.0 hp (1760 rpm) |
| | | | V=7.5 hp (1760 rpm) |
| | | | W=10 hp (1760 rpm) |
| | | | Y=15 hp (1760 rpm) |
| | | | Z=20.0 hp (1760 rpm) |
| | | | 1=25.0 hp (1760 rpm) |
| | | | 2=30.0 hp (1760 rpm) |
| | | | 3=40.0 hp (1760 rpm) |
| | | | 4=50.0 hp (1760 rpm) |
| | | | 5=60.0 hp (1760 rpm) [illegible] |

| 2nd FEATURE—O/A CONTROL |
|---|
| 0=Std (No Actuator) |
| A=3 Pos Econ w/ Sensible Limit |
| B=3 Pos Econ w/ Enthalpy Limit |
| C=Full Mod Econ w/ Sensible Limit |
| D=Full Mod Econ w/ Enthalpy Limit |
| E=DDC Econ Control |
| F=Constant Volume Outside Air |
| G=Option F + Option A |
| H=Option F + Option B |
| J=Option F + Option C |
| K=Option F + Option D |
| L=Option F + Option E |
| M=$CO_2$ Override + Option A |
| N=$CO_2$ Override + Option B |
| P=$CO_2$ Override + Option C |
| Q=$CO_2$ Override + Option D |
| R=$CO_2$ Override + Option E |

| 3rd FEATURE—DISCHARGE LOCATIONS |
|---|
| 0=Bottom Discharge |
| A=Front Discharge |
| B=Back Discharge |
| C=Top Discharge |
| D=End Discharge—Airhandler w/o Vestibule [illegible] |

| 4th FEATURE—RETURN LOCATIONS |
|---|
| 0=Bottom Return |
| A=End Return (no erc or pwr ex) |
| B=Front Return High CFM (no erc or pwr ex) |
| C=Front Return Low CFM (no erc or pwr ex) |
| D=Back Return High CFM (no erc or pwr ex) |
| E=Back Return Low CFM (no erc or pwr ex) |
| F=Front Return High CFM (w/ erc or pwr ex) |
| G=Front Return Low CFM (w/ erc or pwr ex) |
| H=Back Return High CFM (w/ erc or pwr ex) |
| J=Back Return Low CFM (w/ erc or pwr ex) |

### 5th FEATURE—SUPPLY AIR OPTIONS

| A FEATURE—S/A BLOWER CONFIG. | B FEATURE—S/A BLOWER | C FEATURE—S/A MOTOR |
|---|---|---|
| 0=1 Blower w/(Standard efficiency motor) | A=Blower A (27" Diameter) | A=.75 hp (1170 rpm) [illegible] |
| A=2 Blowers w/(Standard efficiency motors) | B=Blower B (30" Diameter) | B=1.0 hp (1170 rpm) [illegible] |
| B=3 Blowers w/(Standard efficiency motors) | C=Blower C (33" Diameter) | C=2.0 hp (1170 rpm) [illegible] |
| C=4 Blowers w/(Standard efficiency motors) | D=Blower D (36.5" Diameter) | D=3.0 hp (1170 rpm) |
| D=1 Blower w/(Premium efficiency motors) | E=Blower E (42.5" Diameter) | E=5.0 hp (1170 rpm) |
| E=2 Blowers w/(Premium efficiency motors) | | F=7.5 hp (1170 rpm) |
| F=3 Blowers w/(Premium efficiency motors) | | G=10 hp (1170 rpm) |
| G=4 Blowers w/(Premium efficiency motors) | | H=15 hp (1170 rpm) |
| H=1 Blower w/(Prem eff mtr) w/VFD | | J=20 hp (1170 rpm) |
| J=2 Blowers w/(Prem eff mtr) w/1-VFD | | K=25 hp (1170 rpm) |
| K=2 Blowers w/(Prem eff mtr) w/2-VFD,s | | L=30 hp (1170 rpm) |
| L=3 Blowers w/(Prem eff mtr) w/1-VFD | | M=40 hp (1170 rpm) |
| M=3 Blowers w/(Prem eff mtr) w/3-VFD's | | N=50 hp (1170 rpm) |
| N=4 Blowers w/(Prem eff mtr) w/1-VFD | | P=60 hp (1170 rpm) [illegible] |
| P=4 Blowers w/(Prem eff mtr) w/2-constant speed and 2-VFD's | | Q=.75 hp (1760 rpm) [illegible] |
| Q=4 Blowers w/(Prem eff mtr) w/4-VFD's | | R=1.0 hp (1760 rpm) [illegible] |
| R=4 Blowers w/(Prem eff mtr) w/2 VFDs | | S=2.0 hp (1760 rpm) [illegible] |
| | | T=3.0 hp (1760 rpm) |
| | | U=5.0 hp (1760 rpm) |
| | | V=7.5 hp (1760 rpm) |
| | | W=10 hp (1760 rpm) |
| | | Y=15 hp (1760 rpm) |
| | | Z=20.0 hp (1760 rpm) |
| | | 1=25.0 hp (1760 rpm) |
| | | 2=30.0 hp (1760 rpm) |
| | | 3=40.0 hp (1760 rpm) |
| | | 4=50.0 hp (1760 rpm) |
| | | 5=60.0 hp (1760 rpm) [illegible] |

### 6th FEATURE—FILTER OPTIONS

| A FEATURE—PRE FILTER TYPE | B FEATURE—FINAL FILTER TYPE | C FEATURE—FILTER OPTIONS |
|---|---|---|
| 0=2" Pleated | 0=Std | 0=Std |
| A=4" Pleated | A=12" Cartridge 85% Eff—Filter Box A | A=CFS Pre Filter |
| B=2" Permanent Frame | B=12" Cartridge 85% Eff—Filter Box B | B=CFS Final Filter |
| C=2" Pre/12" Cartridge 85% Eff.[1] | C=12" Cartridge 85% Eff—Filter Box C | C=Magnehelic Gauge Pre Filter |
| D=2" Pre/12" Cartridge 85% Eff.[1] | D=12" Cartridge 95% Eff—Filter Box A | D=Magnehelic Gauge Final Filter |
| E=2" Pre/12" Cartridge 95% Eff.[1] | E=12" Cartridge 95% Eff—Filter Box B | E=Option A + B |
| F=4" Pre/12" Cartridge 85% Eff.[1] | F=12" Cartridge 95% Eff—Filter Box C | F=Option A + C |
| G=4" Pre/12" Cartridge 85% Eff.[1] | G=30" Bag 85% Eff—Filter Box A | G=Option A + D |
| H=4" Pre/12" Cartridge 95% Eff.[1] | H=30" Bag 85% Eff—Filter Box B | H=Option B + C |
| J=2" Pre/30" Bag 85% Eff.[1] | J=30" Bag 85% Eff—Filter Box C | J=Option B + D |
| K=2" Pre/30" Bag 95% Eff.[1] | K=30" Bag 95% Eff—Filter Box A | K=Option A + B + C |
| L=4" Pre/30" Bag 85% Eff.[1] | L=30" Bag 95% Eff—Filter Box B | L=Option A + B + D |
| M=4" Pre/30" Bag 95% Eff.[1] | M=30" Bag 95% Eff—Filter Box C | M=Option A + C + D |
| | N=Pre Filter Box A (Hi-E Filters)—No Final Filter | N=Option B + C + D |
| Notes: | P=Pre Filter Box B (Hi-E Filters)—No Final Filter | P=Option A + B + C + D |
| [1] Requires Feature 6B option N, P, or Q to be selected | Q=Pre Filter Box C (Hi-E Filters)—No Final Filter | |

| 7th FEATURE—REFRIG. CONTROL |
|---|
| 0=Std |
| A=5 MTDR On & 5 MTDR Off |
| B=20 STDR |
| C=115V Outlet Field Wired |
| D=115V Outlet Factory Wired |
| E=Option A + Option B |
| F=Option A + Option C |
| G=Option A + Option D |
| H=Option A + Option B + Option C |
| J=Option A + Option B + Option D |
| K=Option B + Option C |
| L=Option B + Option D |

| 8th FEATURE—REFRIG. OPTIONS |
|---|
| 0=Std |
| A=Hot Gas Bypass Lead Stage (HGB) |
| B=Hot Gas Reheat Coil (HGRC) |
| C=Modulating Hot Gas Reheat Coil (MHGR) |
| D=HGB Lead + HGB Lag |
| E=HGB Lead + HGRC |
| F=HGB Lead + MHGR |
| G=HGB Lead + HGB Lag + HGRC |
| H=HGB Lead + HGB Lag + MHGR |

| 9th FEATURE—REFRIG. ACCESSORIES |
|---|
| 0=Std |
| A=Sight Glass |
| B=Compressor Isolation Valves |
| C=A + B |

| 10th FEATURE—POWER OPTIONS |
|---|
| 0=Std Power Block |
| A=Power Switch (225 amps) |
| B=Power Switch (400 amps) |
| C=Power Switch (600 amps) |
| D=Power Switch (800 amps) |
| E=Power Switch (1,200 amps) |

| 11th FEATURE—SAFETY OPTIONS |
|---|
| 0=Std |
| A=R/A & S/A Firestat |
| B=R/A Smoke Detector |
| C=S/A Smoke Detector |
| D=R/A & S/A Smoke Detector |
| E=R/A & S/A Firestat + R/A SD |
| F=R/A & S/A Firestat + S/A SD |
| G=R/A & S/A FS + R/A & S/A SD |

| 12th FEATURE—CONTROLS |
|---|
| 0=Std |
| A=Low Limit Controls |
| B=Phase & Brown Out Protection |
| C=LLC + Phase & Brown Out Protection |

| 13th FEATURE—SPECIAL CONTROLS |
|---|
| 0=Std |
| A=W973 Honeywell Controller |
| B=W7100 Honeywell Controller |
| C=W7100 Controller + Expansion Board |
| D=VAV Unit Controller |
| E=Constant Volume Unit Controller |
| F=Make Up Air Unit Controller |
| G=Heat Cool Changeover Controller |
| H=Field Installed DDC Controls by Others |
| J=Factory Installed DDC Controls by Others |

### 14th FEATURE—PREHEAT OPTIONS

| A FEATURE—CONFIGURATION | B FEATURE—SIZING |
|---|---|
| 0=Std (No Preheat) | 0=Std (No Preheat) |
| A=Hot Water Coil Preheat (Req'd option box)[1] | A=Heat Qty A |
| B=Steam Distributing Coil Preheat (Req'd box)[1] | B=Heat Qty B |
| C=Hot Water Coil Preheat O/A | C=Heat Qty C |
| D=Steam Distributing Coil Preheat O/A | D=Heat Qty D |
| E=Direct Fired Heat 100% O/A [illegible] | |
| Notes: | |
| [1] Requires an option box from Feature 15 | |

| 15th FEATURE—OPTION BOXES |
|---|
| 0=Std |
| A=2ft Box Position 1 |
| B=2ft Box Position 2 |
| C=2ft Box Position 3 |
| D=2ft Box Position 4 |
| E=4ft Box Position 1 |
| F=4ft Box Position 2 |
| G=4ft Box Position 3 |
| H=4ft Box Position 4 |
| J=6ft Box Position 1 |
| K=6ft Box Position 2 |
| L=6ft Box Position 3 |
| M=6ft Box Position 4 |
| N=8ft Box Position 1 |
| P=8ft Box Position 2 |
| Q=8ft Box Position 3 |
| R=8ft Box Position 4 |

| 16th FEATURE—CABINET OPTIONS |
|---|
| 0=Std |
| A=Stainless Steel Drain Pans |
| B=Marine Service Lights |
| C=Base Insulation |
| D=Option A + B |
| E=Option A + C |
| F=Option B + C |
| G=Option A + B + C |

| 17th FEATURE—CABINET OPTIONS |
|---|
| 0=Std |
| A=Access door windows |
| B=Burglar Bars |
| C=Perf Liner S/A Plenum |
| D=Perf Liner R/A Plenum |
| E=R/A Plenum Sound Trap |
| F=Option A + B |
| G=Option A + C |
| H=Option A + D |
| J=Option A + E |
| K=Option B + C |
| L=Option B + D |
| M=Option B + E |
| N=Option C + D |
| P=Option C + E |
| Q=Option A + B + C |
| R=Option A + B + D |
| S=Option A + B + E |
| T=Option A + C + D |
| U=Option A + C + E |
| V=Option B + C + D |
| W=Option B + C + E |
| Y=Option A + B + C + D |
| Z=Option A + B + C + E |

| 18th FEATURE—CUSTOMER CODE |
|---|
| 0=ETL U.S.A. Listing |
| A=ETL U.S.A. + Canada Listing |
| B=No ETL |

| 19th FEATURE—CODE OPTIONS |
|---|
| 0=Std |
| A=M.E.A. (New York) |
| B=Chicago—Cool & Gas |
| C=Chicago—Cool & Electric Heat |
| D=Chicago—Cool Only |
| E=Chicago—Gas Only |
| F=Chicago—Electric Heat Only |
| G=Chicago—No Cool No Heat |

| 20th FEATURE—UNIT CONFIGURATION |
|---|
| 0=Std (One Piece Unit) |
| A=Two Piece Unit (Split After Evap Coil) |

| 21st FEATURE—EVAP & WATER CONDENSER |
|---|
| 0=Std (No Evap or Water Condenser) |
| A=Basic Package (Evap Cond or Water Cooled) |
| B=Low Ambient Package (Evap Cond) |
| C=Balancing Valves (Water Cond) |
| D=Single Point Water Connection (Water Cond) |
| E=Insulated Service Vestibule (Water Cond & Electric Heater) |
| F=Motorized Shut-off Valve (Water Cond) |
| G=Head Pressure Control (Water Cond) |
| H=Option C + D |
| J=Option C + E |
| K=Option C + F |
| L=Option C + G |
| M=Option D + E |
| N=Option D + F |
| P=Option D + G |
| Q=Option E + F |
| R=Option E + G |
| S=Option F + G |
| T=Option C + D + E |
| U=Option C + D + F |
| V=Option C + D + G |
| W=Option D + E + F |
| Y=Option D + E + G |
| Z=Option E + F + G |
| 1=Option C + D + E + F |
| 2=Option C + D + E + G |
| 3=Option C + D + F + G |
| 4=Option C + E + F + G |
| 5=Option C + D + E + F + G |

| 22nd FEATURE—BLANK |
|---|
| 0=Std |

| 23rd FEATURE—TYPE |
|---|
| B=Std (Includes 'Gray Paint') |
| U=Special Price Authorization & Special Paint |
| X=Special Price Authorization & Gray Paint |

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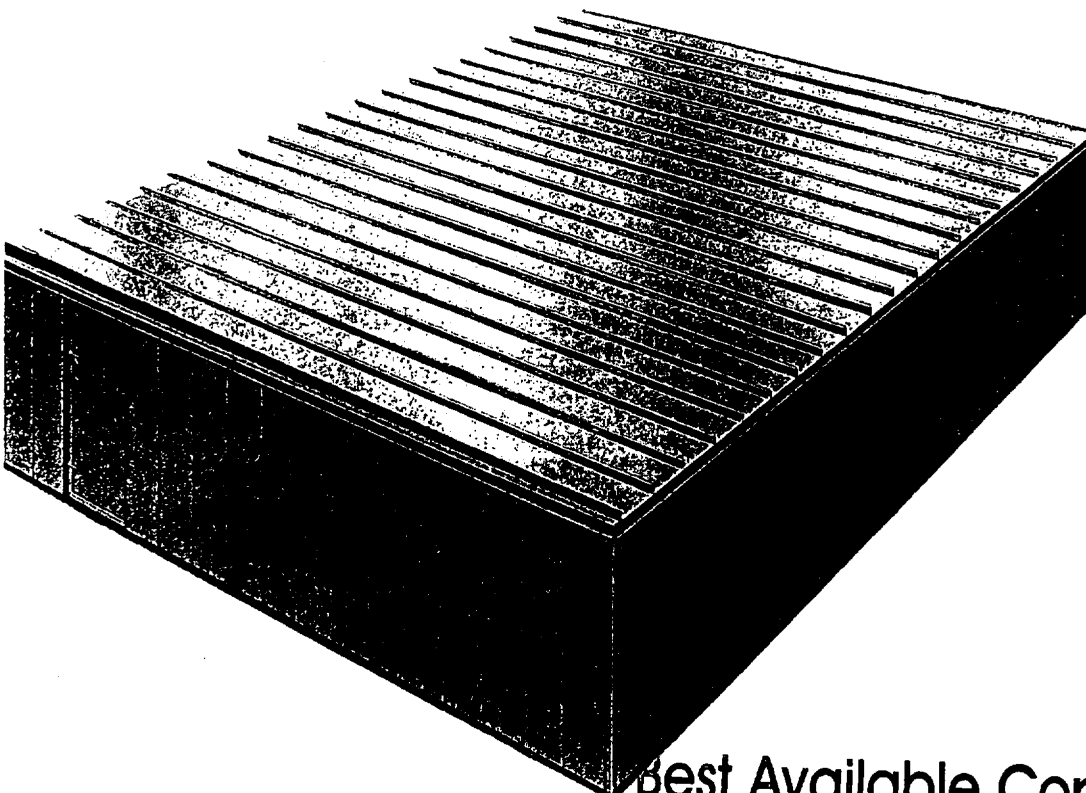
# Custom Penthouse

## 200 – 410 Tons
## Cooling-only VAV configurations



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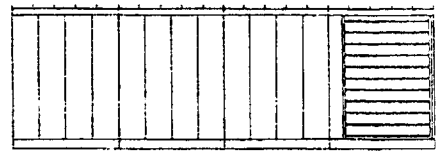
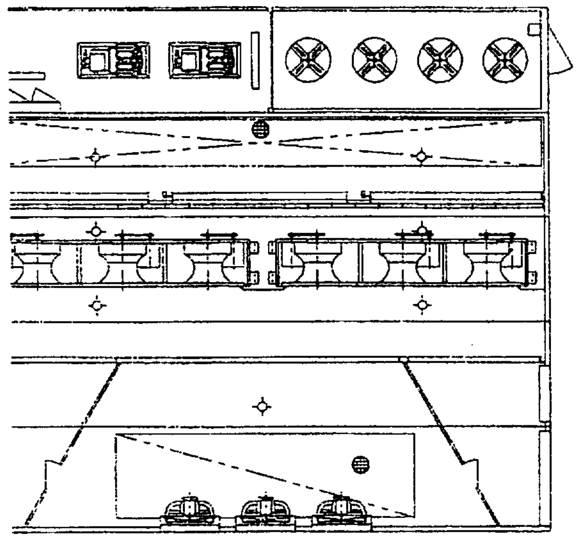
## *Selection Guide*

# *Look into a Mammoth Custom Penthouse for flexibility, efficiency, and reliability*



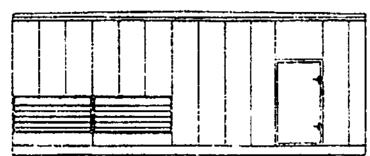
For your next HVAC design, take advantage of lower first costs, shorter construction cycles and time-proven performance. Enjoy complete system flexibility, without the design, procurement and labor costs normally associated with field-built systems.

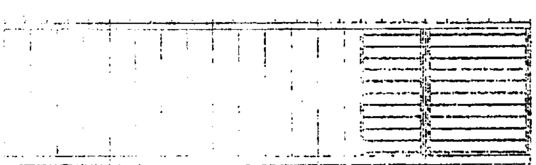


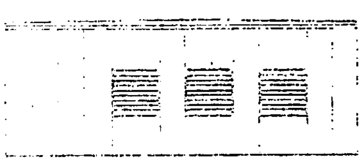
### *Specify a Mammoth Custom Penthouse*

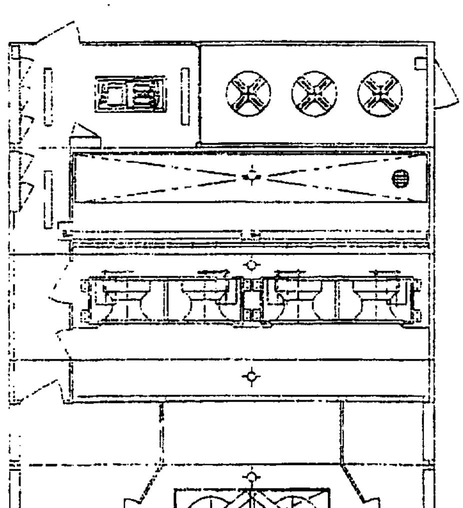
Mammoth has engineered the Custom Penthouse to meet the conditioning needs of office buildings, retail establishments and warehouse/industrial facilities with cooling requirements from 200 to 600 tons.

The following data provides an overview of Custom Penthouse configurations and performance characteristics available for variable air volume (VAV), cooling-only applications. If your project requires additional capacity or mechanical equipment, the Custom Penthouse can be engineered to satisfy those requisites. After all, the number of possible options ends only when you are satisfied.



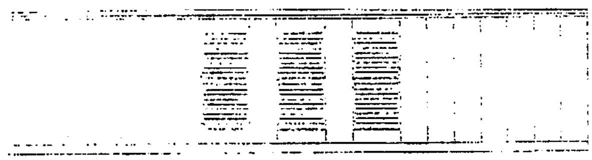


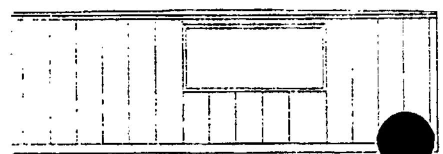




# *Custom Penthouse standard features*

- Evaporative condenser with staging/unloading capability
- York semi-hermetic reciprocating compressors
- Supply and return fan staging
- DX cooling and fan redundancy
- Custom exterior color (air dry)
- Walk-in service vestibule
- Full interior service lighting
- Factory-wired 15-amp GFI convenience outlet
- Remote unit status monitoring panel
- Vari-Cone® air modulator
- Four-inch 30% efficiency filters
- Low-leakage outside/return air dampers
- Full economizer control
- Water treatment interface for condenser
- Single point main and temperature control
- Factory certified start-up
- ETL labeled





# *Optional features*

- Screw compressors
- Factory fabricated, field installed curbing
- Direct digital control (DDC) interface or complete DDC unit controls
- Acoustical inner liner panels
- Access stairways
- Custom-sized DX coils and supply air openings (requires factory confirmation)
- Fire and smoke sequence of operation
- Custom remote control panel
- Factory-certified final field piping/ electrical connections

This is just a sampling of options available for the Mammoth Custom Penthouse. For more information, consult your Mammoth Representative.

## UNIT PHYSICAL AND NOMINAL PERFORMANCE DATA

| MODEL | Propeller Exhaust | | | | | | Power Return | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2102 | 2602 | 3002 | 3502 | 4203 | 4403 | 2102 | 2602 | 3002 | 3502 | 4203 | 4403 |
| Condenser KW | 164.7 | 199.8 | 225.0 | 275.5 | 315.0 | 340.4 | 164.7 | 199.8 | 225.0 | 275.5 | 315.0 | 340.4 |
| Unit Total Full Load Amps (460/3/60) | 427.0 | 555.2 | 591.6 | 777.8 | 856.0 | 890.0 | 474.0 | 579.2 | 627.6 | 803.8 | 892.0 | 944.0 |
| **DX Cooling Capacity** | | | | | | | | | | | | |
| **MBH/Tons** Total | 2400/200 | 2940/245 | 3300/275 | 3960/330 | 4560/380 | 4920/410 | 2400/200 | 2940/245 | 3300/275 | 3960/330 | 4560/380 | 4920/410 |
| Sensible | 1825/152 | 2215/184 | 2485/207 | 2985/248 | 3405/283 | 3740/311 | 1825/152 | 2215/184 | 2485/207 | 2985/248 | 3405/283 | 3740/311 |
| **DX Coil** | | | | | | | | | | | | |
| Rows/Fins per Inch | 5/10 | 5/10 | 5/10 | 5/10 | 5/10 | 5/10 | 5/10 | 5/10 | 5/10 | 5/10 | 5/10 | 5/10 |
| Square Feet | 132 | 157 | 177 | 211 | 241 | 271 | 132 | 157 | 177 | 211 | 241 | 271 |
| **Main Supply Fan Data** | | | | | | | | | | | | |
| Supply Air CFM | 76,000 | 93,100 | 104,500 | 125,400 | 144,400 | 155,800 | 76,000 | 93,100 | 104,500 | 125,400 | 144,400 | 155,800 |
| Supply Air TSP ("WC) | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 |
| Supply Air Brake HP/ Actual HP | 112/120 | 128/160 | 148/160 | 171/240 | 204/240 | 222/240 | 112/120 | 128/160 | 148/160 | 171/240 | 204/240 | 222/240 |
| **Power Return Air/ Exhaust Air Fan Data** | | | | | | | | | | | | |
| Return Air CFM | N/A | N/A | N/A | N/A | N/A | N/A | 68,400 | 83,700 | 94,000 | 112,800 | 129,000 | 140,200 |
| Return Air ESP ("WC) | N/A | N/A | N/A | N/A | N/A | N/A | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Return Air Brake HP/ Actual HP | N/A | N/A | N/A | N/A | N/A | N/A | 58/60 | 45/50 | 55/60 | 57/60 | 72/75 | 83/90 |
| **Prop Exhaust Fan Data** | | | | | | | | | | | | |
| Exhaust Air CFM | 68,400 | 83,700 | 94,000 | 112,800 | 129,000 | 140,200 | N/A | N/A | N/A | N/A | N/A | N/A |
| Exhaust Air ESP ("WC) | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | 0.50 | N/A | N/A | N/A | N/A | N/A | N/A |
| Actual HP | 22.5 | 30.0 | 30.0 | 37.5 | 45.0 | 45.0 | N/A | N/A | N/A | N/A | N/A | N/A |
| **Filters (4")** 35% Eff. – Square Feet | 167.0 | 208.0 | 208.0 | 267.0 | 267.0 | 333.0 | 167.0 | 208.0 | 208.0 | 267.0 | 267.0 | 333.0 |
| **Louver/Damper Data** | | | | | | | | | | | | |
| Outside Air Louver-Sq. Ft. | 104.0 | 184.0 | 184.0 | 184.0 | 184.0 | 184.0 | 104.0 | 184.0 | 184.0 | 184.0 | 184.0 | 184.0 |
| Outside Air Motorized Damper-Sq. Ft. | 68.0 | 93.0 | 93.0 | 160.0 | 160.0 | 160.0 | 68.0 | 93.0 | 93.0 | 160.0 | 160.0 | 160.0 |
| Return Air Motorized Damper-Sq. Ft. | 86.0 | 103.0 | 103.0 | 163.0 | 163.0 | 163.0 | 86.0 | 103.0 | 103.0 | 163.0 | 163.0 | 163.0 |
| Exhaust Air Non-Motorized Damper-Sq. Ft. | 52.0 | 69.0 | 69.0 | 86.0 | 104.0 | 104.0 | 68.0 | 75.0 | 75.0 | 101.0 | 101.0 | 101.0 |
| Size - Length x Width | 30' x 25' | 37½' x 30' | 37½' x 30' | 37½' x 45' | 37½' x 45' | 37½' x 45' | 30' x 25' | 37½' x 30' | 37½' x 30' | 37½' x 45' | 37½' x 45' | 37½' x 45' |
| Operating Weight (lbs.) | 43,967 | 59,352 | 59,880 | 80,216 | 83,208 | 84,057 | 44,924 | 60,405 | 61,033 | 81,935 | 84,742 | 85,591 |

### DESIGN CRITERIA

1) All data measured at sea level.
2) Cooling loads based on 80°/67°F entering air temperature to DX cooling coil.
3) DX cooling capacity based on DX saturated suction temperature of 45°F and 78°F entering wet bulb design temperature.
4) All data based upon a Custom Penthouse unit height of 10 feet 4 inches only.
5) For smaller/larger capacity units, please consult your Mammoth representative.

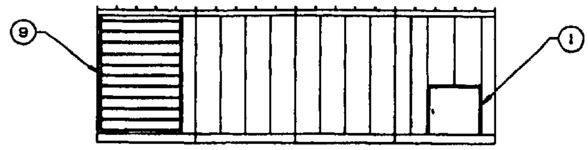


CL 307

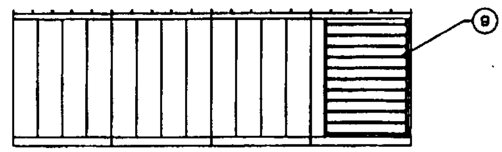
*REFERENCE*

Propeller Exhaust –
Model 2102

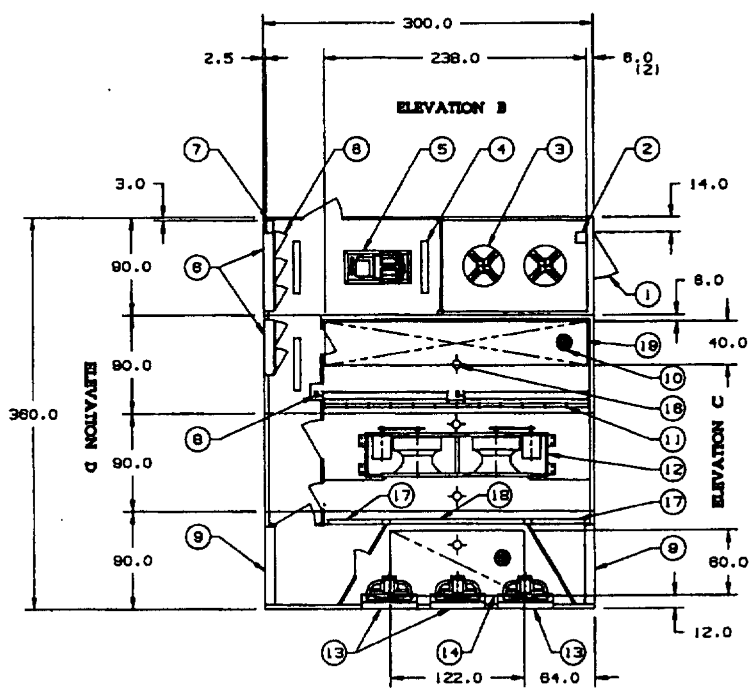
**Mammoth®**



ELEVATION C

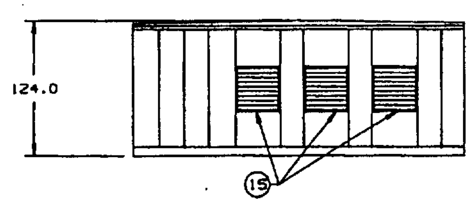


ELEVATION D

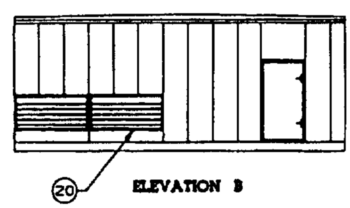



ELEVATION A

| ITEM | DESCRIPTION |
|---|---|
| 1 | Sump access |
| 2 | 10" x 10" Supply and drain water chase |
| 3 | Condenser fans |
| 4 | Fluorescent lights |
| 5 | Compressors |
| 6 | Control box |
| 7 | 6" x 12" Electrical chase |
| 8 | Evaporator coils |
| 9 | Outside air louvers |
| 10 | Bar grate |
| 11 | 4" filters |
| 12 | Main supply fans |
| 13 | Prop exhaust fans |
| 14 | Return opening |
| 15 | Exhaust louvers |
| 16 | Incandescent vapor proof lights |
| 17 | Outside air dampers |
| 18 | Return air dampers |
| 19 | Supply opening |
| 20 | Sump intake |




ELEVATION A

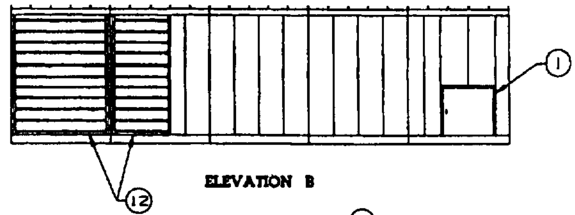


ELEVATION B

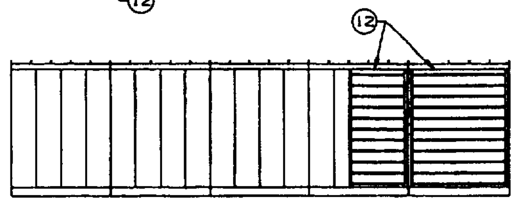
*REFERENCE*

Propeller Exhaust –
Model 2602
Model 3002

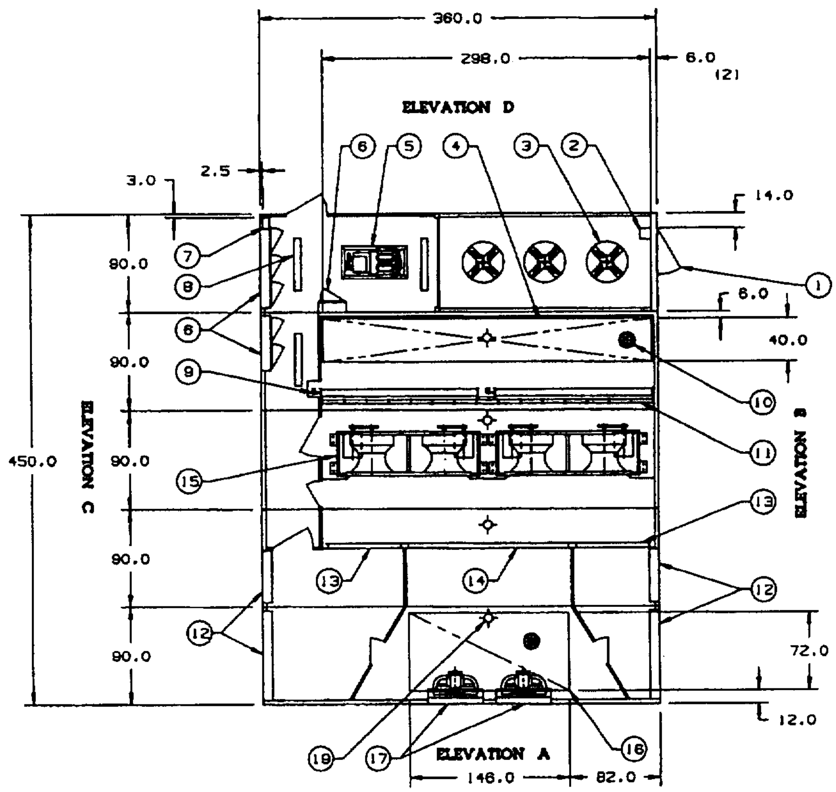
**Mammoth®**



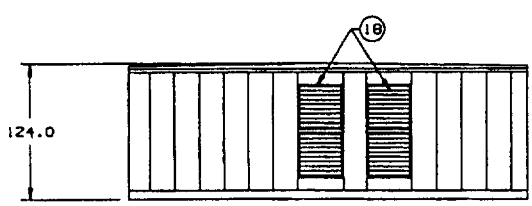
ELEVATION B



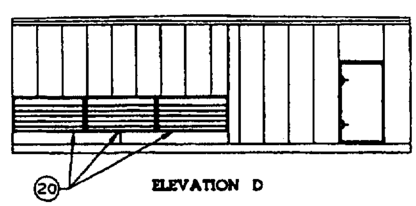
ELEVATION C




| ITEM | DESCRIPTION |
|---|---|
| 1 | Sump access |
| 2 | 10" x 10" Supply and drain water chase |
| 3 | Condenser fans |
| 4 | Supply opening |
| 5 | Compressors |
| 6 | Control box |
| 7 | 6" x 12" Electrical chase |
| 8 | Fluorescent lights |
| 9 | Evaporator coils |
| 10 | Bar grate |
| 11 | 4" filters |
| 12 | Outside air louvers |
| 13 | Outside air dampers |
| 14 | Return air dampers |
| 15 | Supply fans |
| 16 | Return opening |
| 17 | Prop exhaust fans |
| 18 | Exhaust louvers |
| 19 | Incandescent vapor proof lights |
| 20 | Sump intake |




ELEVATION A



ELEVATION D



CL 309

*REFERENCE*

Propeller Exhaust –
Model 3502
Model 4203
Model 4403

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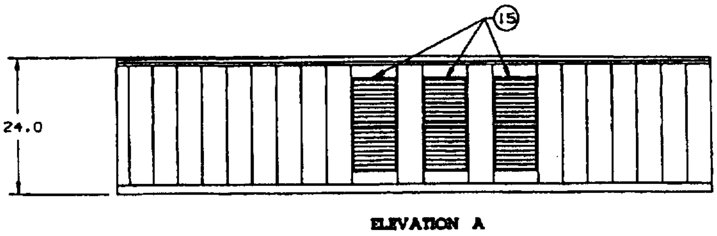
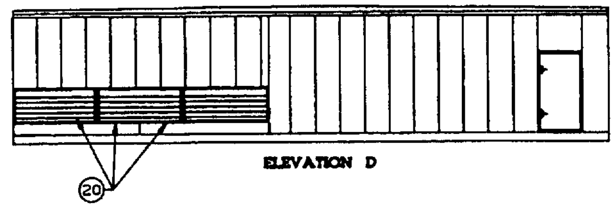
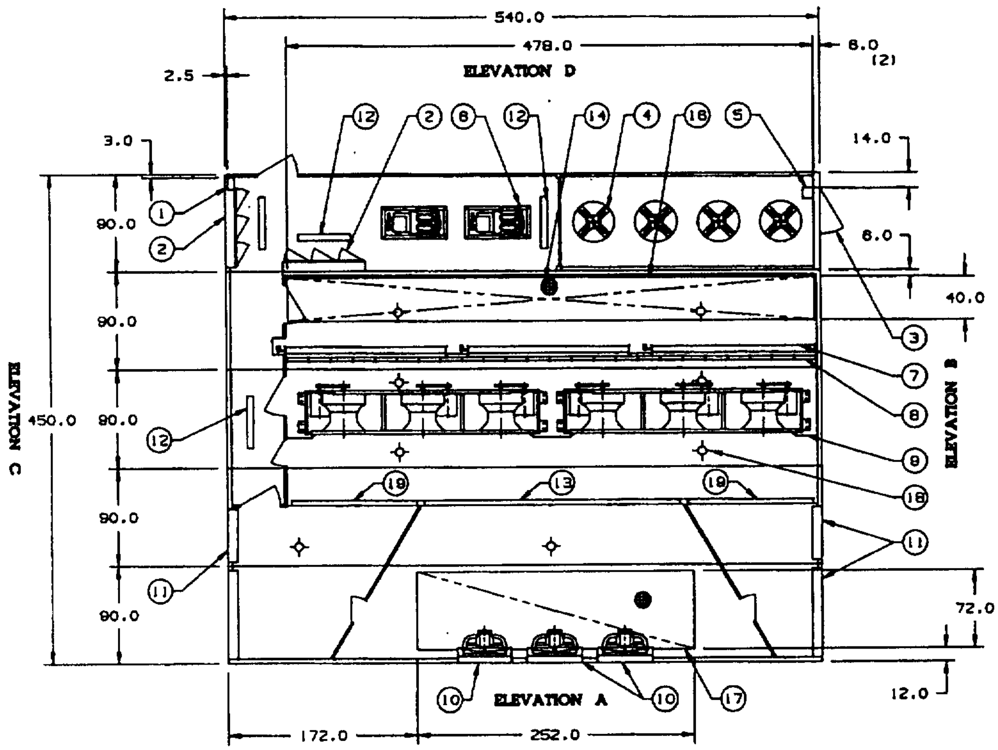
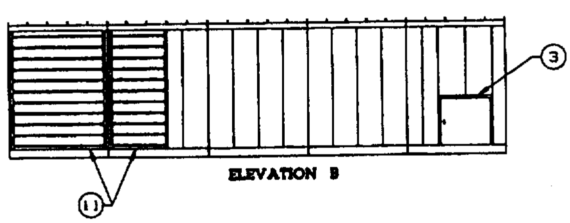
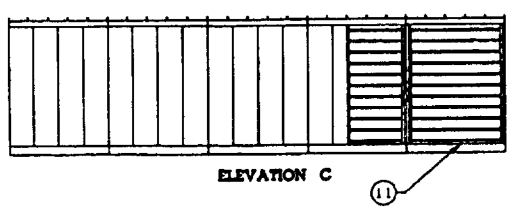



| ITEM | DESCRIPTION |
|---|---|
| 1 | 6" x 12" Electrical chase |
| 2 | Control box |
| 3 | Sump access |
| 4 | Condenser fans |
| 5 | 10" x 10" Supply and drain water chase |
| 6 | Compressors |
| 7 | Evaporator coils |
| 8 | 4" Filters |
| 9 | Supply fans |
| 10 | Prop exhaust fans |
| 11 | Outside air louvers |
| 12 | Fluorescent lights |
| 13 | Return air dampers |
| 14 | Bar grate |
| 15 | Exhaust louvers |
| 16 | Supply opening |
| 17 | Return opening |
| 18 | Incandescent vapor proof lights |
| 19 | Outside air dampers |
| 20 | Sump intake |



*REFERENCE*

Power Return –
Model 2102

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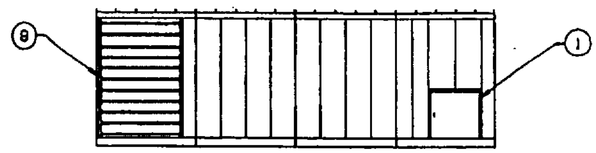


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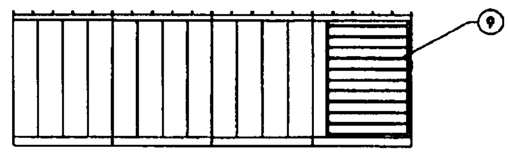
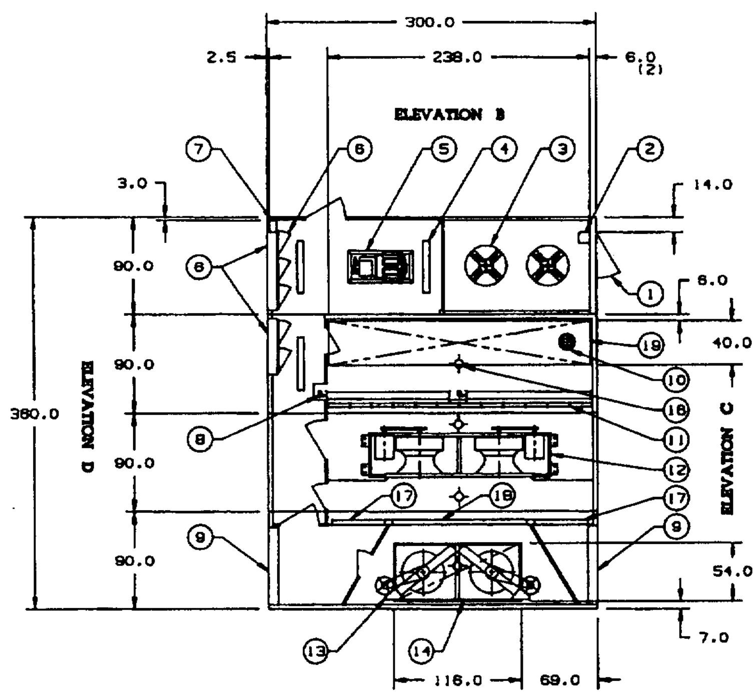
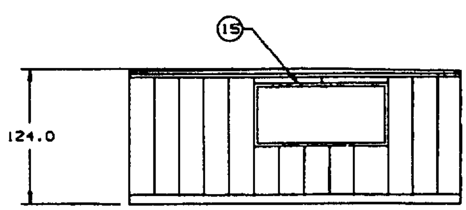



ELEVATION D

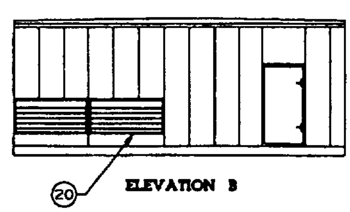



ELVATION A

| ITEM | DESCRIPTION |
|---|---|
| 1 | Sump access |
| 2 | 10" x 10" Supply and drain water chase |
| 3 | Condenser fans |
| 4 | Fluorescent lights |
| 5 | Compressors |
| 6 | Control box |
| 7 | 6" x 12" Electrical chase |
| 8 | Evaporator coils |
| 9 | Outside air louvers |
| 10 | Bar grate |
| 11 | 4" filters |
| 12 | Supply fans |
| 13 | Power return fans |
| 14 | Return opening |
| 15 | Relief panel |
| 16 | Incandescent vapor proof lights |
| 17 | Outside air dampers |
| 18 | Return air dampers |
| 19 | Supply opening |
| 20 | Sump intake |




ELEVATION A




ELEVATION B

*REFERENCE*

Power Return –
Model 2602
Model 3002

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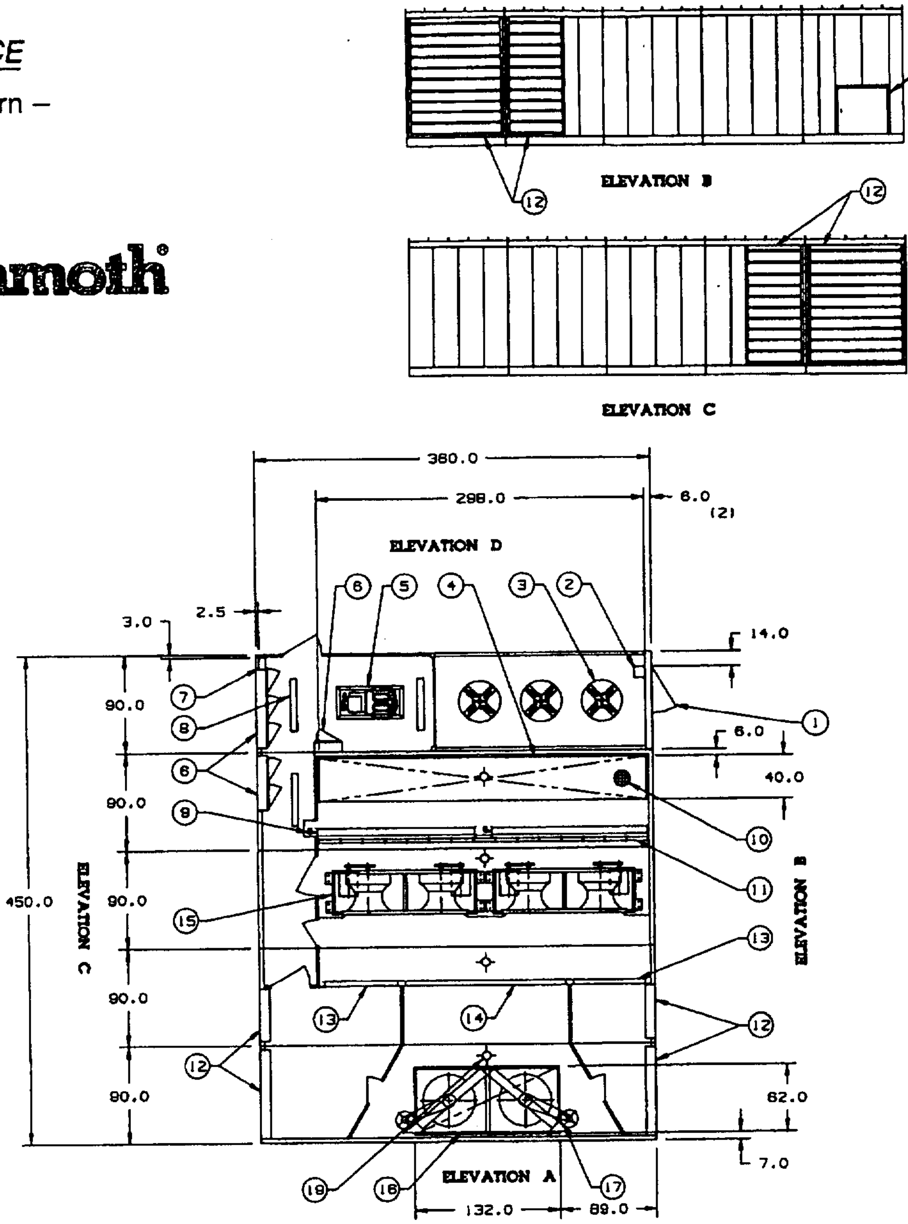
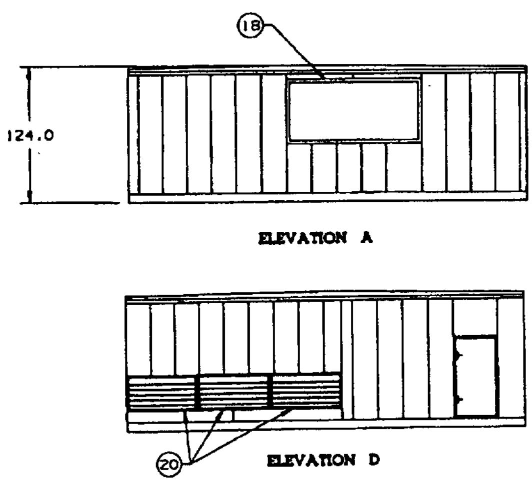



| ITEM | DESCRIPTION |
|---|---|
| 1 | Sump access |
| 2 | 10" x 10" Supply and drain water chase |
| 3 | Condenser fans |
| 4 | Supply opening |
| 5 | Compressors |
| 6 | Control box |
| 7 | 6" x 12" Electrical chase |
| 8 | Fluorescent lights |
| 9 | Evaporator coils |
| 10 | Bar grate |
| 11 | 4" filters |
| 12 | Outside air louvers |
| 13 | Outside air dampers |
| 14 | Return air dampers |
| 15 | Supply fans |
| 16 | Return opening |
| 17 | Power return fans |
| 18 | Relief panel |
| 19 | Incandescent vapor proof lights |
| 20 | Sump intake |



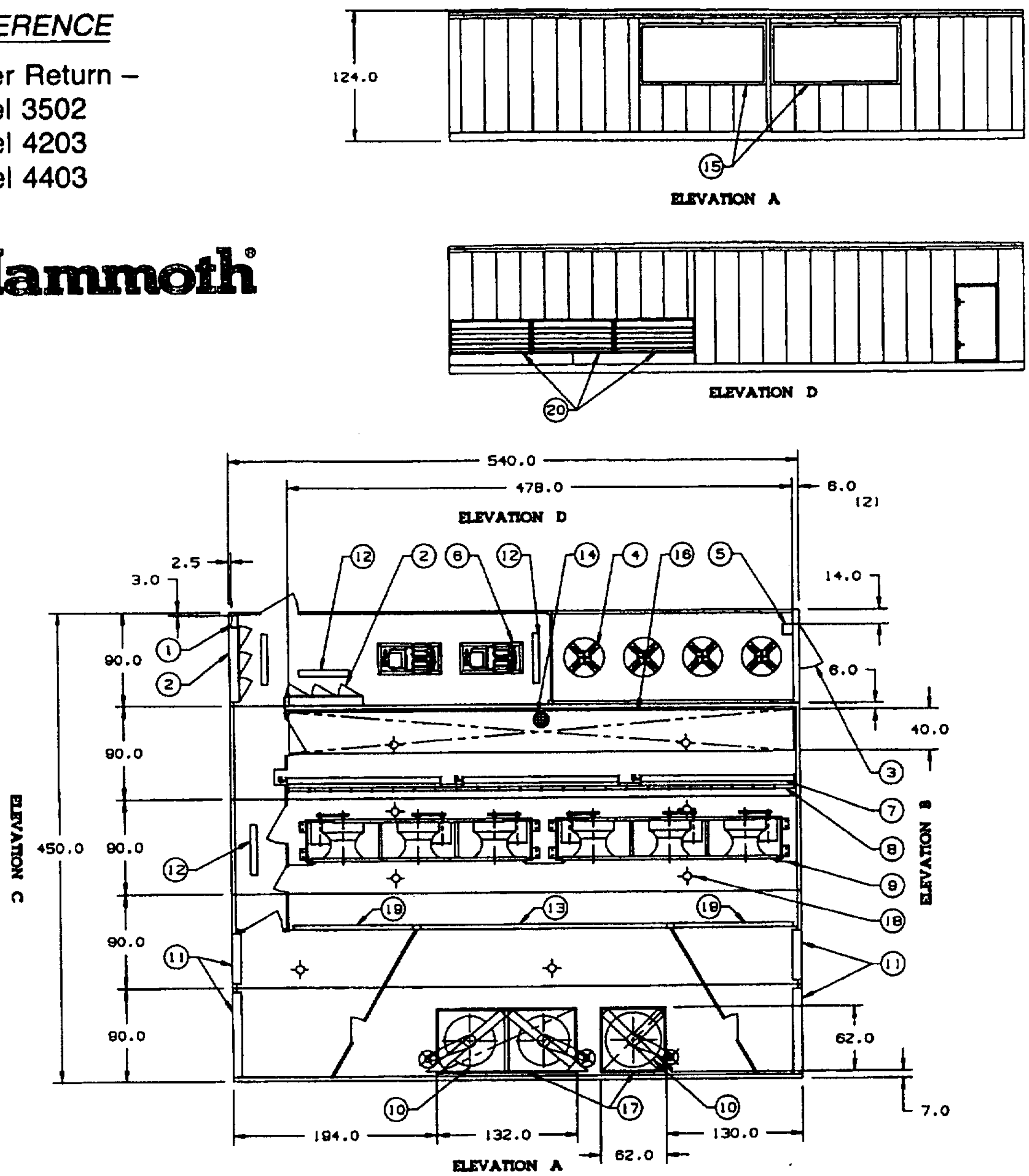



CL 312

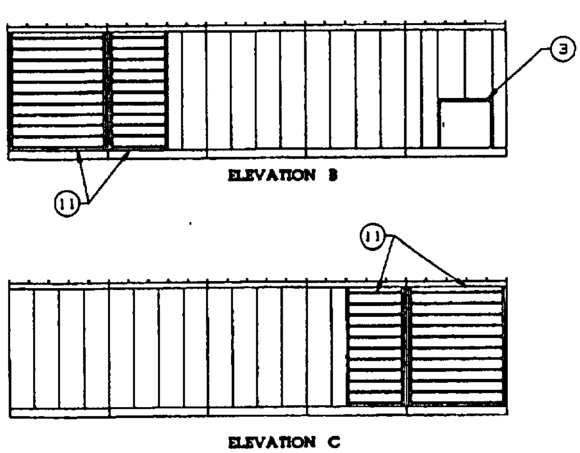
*REFERENCE*

Power Return –
Model 3502
Model 4203
Model 4403

**Mammoth®**




| ITEM | DESCRIPTION |
|---|---|
| 1 | 6" x 12" Electrical chase |
| 2 | Control box |
| 3 | Sump access |
| 4 | Condenser fans |
| 5 | 10" x 10" Supply and drain water chase |
| 6 | Compressors |
| 7 | Evaporator coils |
| 8 | 4" Filters |
| 9 | Supply fans |
| 10 | Power return fans |
| 11 | Outside air louvers |
| 12 | Fluorescent lights |
| 13 | Return air dampers |
| 14 | Bar grate |
| 15 | Relief panel |
| 16 | Supply opening |
| 17 | Return opening |
| 18 | Incandescent vapor proof lights |
| 19 | Outside air dampers |
| 20 | Sump intake |



# UNIT SPECIFICATIONS

The Penthouse unit shall be Mammoth Custom Penthouse unit of the type, size, and capacity as required and listed in the equipment schedule. Each unit shall include the pre-assembled components in accordance with the following detailed specifications.

## Construction

### Cabinet

Each Penthouse unit shall be fabricated in one (1) or more sections ready for field installation. Each section shall be fabricated with a structural steel base reinforced and braced to permit the shipping and general handling of the completed section without damage to the section or internal components. The section base shall be fabricated with an 8-inch, 11.5 lb. per foot, structural member perimeter and have 8-, 11-, and 14-gauge formed structural cross members at 30" centers maximum. Additional cross members or reinforcements shall be placed at critical locations to support internal components. The base section shall have a floor of 14-gauge galvanized steel, insulated with 4-inch, 1½ lb. density fiberglass insulation and a 1/2" blanket type, dual-density construction insulation providing acoustical sound absorption capabilities. The insulation shall be retained on the underside by hardware cloth. Lifting points for the section shall be part of the section base.

The section exterior wall structure shall be fabricated of formed 11 and 14-gauge members. The exterior siding shall be 22-gauge pre-painted galvanized steel fabricated and assembled to provide an embossed exterior surface. The wall shall be insulated with 4-inch, 1½ lb. fiberglass insulation for minimum "R" value of 16.3. The interior surface of the wall shall form the air seal and shall be fabricated from 20-gauge galvanized steel. No exposed insulation shall be permitted in the air stream. Foil back or rigid board exposed stick-on insulation will not be permitted.

The top frame structure shall be fabricated of 11- and 14-gauge steel. The interior surface shall form the air seal and shall be fabricated from 20-gauge galvanized steel. The roof shall be insulated with 4-inch, 1½ lb. density fiberglass for minimum "R" value of 16.3. The roof exterior shall be constructed of 18"-wide roll-formed panel, of 24-gauge galvalume material with 2¾" standing seams. The roof shall be sloped a minimum of 2".

Sections shall be designed to be joined together by bolting through mating frame structure. The section frame shall be completely prime painted after fabrication to prevent rusting.

### Service Vestibule

Each unit shall be provided with a full-height, internal walk-in service corridor. A double-wall insulated partition shall be used to separate the airflow equipment from the service corridor. The partition shall be fabricated with a 2" structural frame of 14-gauge galvanized steel, 20-gauge galvanized steel skins, and insulated with 2-inch, 1½ lb. fiberglass insulation. The service corridor floor shall be constructed of 12-gauge treadplate.

### Doors

The external access door(s), and service corridor access door(s) shall be fabricated with an outer skin of 18-gauge galvanized steel, an inner skin of 20-gauge galvanized steel and insulated with 2-inch, 1½ lb. fiberglass insulation. The door shall have a continuous hinge mounted to a 12-gauge door frame. A continuous vinyl bulb gasket shall seal between the door and frame. The access door(s) shall be secured with latches which are operable from both sides. External vestibule access door(s) shall be 36" x 75¾". Other access door(s) shall be 24" x 75¾". Internal access door(s) serving the airstream shall be provided with 6" x 6" sight ports.

## DX Cooling

### Compressors

The compressors shall be of the semi-hermetic, reciprocating type, operating at no more than 1750 RPM, refrigerant gas-cooled, with three-phase inherent overload protection, with voltage available at 460-480 Volts, and "UL" listed.

Lubrication is force-fed by a self-priming reversible, gear-type oil pump to all crankcase surfaces through a fine mesh stainless steel oil strainer, with relief internal to housing conforming to ASHRAE/ANSI Code. A 350-Watt crankcase oil heater shall be supplied to maintain oil temperature during shutdown periods. Tight-seating suction and discharge stop valves are seal cap-type with pressure taps and sweat-type flanged adapters.

Capacity-reduction is accomplished by an oil pressure-actuated cylinder unloading solenoid valve located on compressor crankcase cover plate. Solenoids are controlled by Mammoth factory controls with all compressors capable of four steps of capacity control.

Compressors are tested at 330 PSI with the discharge side further tested to 450 PSI and charged with oil and R-22 to assure a sealed and dry system before final field connections are made.

### Evaporative Condenser

The evaporative condenser coils shall have all prime surface staggered copper tubes, copper headers, and ABS tube sheets to allow for expansion and contraction while avoiding galvanic corrosion. A subcooler integral to the condenser coil shall provide a minimum of 10° F. liquid subcooling. The coils shall be factory leak tested at 400 PSIG nitrogen under water.

The sump shall be constructed of welded 14-gauge type 304L stainless steel below water level and 20-gauge type 430 stainless steel above water line. The sump shall be equipped with a non-mechanical electronic water level control with a brass solenoid valve in the fill line for positive shutoff. A manual 2" brass drain valve, and electric pipe heating cable shall be provided.

The water circulating pump shall be a close coupled, bronze fitted centrifugal type with mechanical seal. Pump suction and discharge lines shall have flexible connections. A type 304 stainless steel pump suction strainer shall be provided which is easily removed for cleaning. The spray header shall be PVC with non-clogging brass spray nozzles, which thoroughly wet all coil surfaces to give maximum heat transfer and minimum scaling. An automatic, factory-set, field-adjustable sump water bleed shall be provided. Units shall be factory piped and tested, ready for 1¼" supply water and 2" drain line hookup.

### Evaporator

The direct expansion evaporator coils shall be fabricated from staggered 1/2" O.D. x .017 wall seamless copper tubing expanded into plate-type aluminum fins to form a positive mechanical and thermal bond. The fins shall have full drawn collars to completely cover the copper tubes. They shall be factory leak tested at a minimum of 400 PSIG under water. Evaporator coils shall be provided with thermostatic expansion valves equipped with external equalizer lines and adjustable for superheat. Refrigerant shall be fed to the coil circuits by brass distributors.

Each evaporator coil shall be provided with a drain pan which shall be fabricated of galvanized sheet steel and coated with corrosion resistant mastic material, which shall be fire resistant (shall meet wet flammability per ASTM D93-73 and dry flammability per ASTM E84-70), provide vibration dampening and thermal insulation. The drain pan(s) shall extend beyond the leaving side of the coil and underneath the cooling coil connections and shall have a common threaded condensate drain connection extending through the unit base frame.

### Refrigerant Circuits

The refrigerant circuits shall be multiple independent circuits which shall be factory piped, tested, dehydrated and fully charged with oil and refrigerant R-22 (holding charge only). Field connections are required between sections. Each refrigerant circuit shall include liquid line service and charging valves, removable core filter drier, sight glass, liquid line solenoid valve, suction and discharge line check valves and compressor service valves.

## *Supply Air Fans*

### Airfoil Fans

The fan wheels shall be multiple airfoil, single width/single inlet-SAS type, secured to a machined, ground and polished solid steel shaft. The shaft shall be coated with a rust inhibitor and shall be supported by two outboard bearings. The fan assembly shall be dynamically balanced. Bearings shall be of the self-aligning ball bearing pillow block type and shall be designed for a minimum of 200,000 hours average life. Drive shall be by means of multiple V-belts. Motor and fan assembly shall be mounted on a heavy-duty steel frame supported by springs with 1-inch deflection (2-inch deflection available).

### Variable Air Volume – Varicone®

The unit shall be capable of delivering a variable air volume by means of a conical spun-steel disk which slides through each fan inlet cone to modulate air flow from 100% open to a tight shut off. The disk is mounted on a rigid stainless steel sleeve with graphite impregnated bearings between it and the fan wheel shaft. Neither the sleeve assembly nor the control disk rotate. Position control is attained by the use of a non-binding ball-and-screw activator.

## *Outside And Return Air Dampers*

Dampers are mounted within a 14-gauge galvanized die-formed channel. The construction of the airfoil shaped blade is of extruded aluminum double wall, with a 1/2 inch, 16-gauge plated square tube axle, keyed into the 12-gauge screw compression pivot arms. Cross linkage rails are fabricated from 12-gauge galvanized 1¼ x ¼ inch angle. Pivot bearings 3/4 x 3/16 inch plated steel. The axle bushings shall be injected molded from delrin. All blade edges are extruded with inflatable lip, fully operational in ambient conditions ranging from -50° F to 275° F. The leakage rate shall be 1.90 CFM at 1.0 (Inches WC) to 5.2 CFM per each square foot of damper area at 4.0 (inches WC) static pressure across blade surface.

### Outside Air Intake Louvers

Outside air louvers shall be of a storm-proof design and shall be provided with 1/2" x 1/2" galvanized bird screen. A fully insulated divider shall be provided to separate outside air from return air.

## *Power Return/Exhaust Fans*

### Airfoil Fans

The fan wheels shall be multiple airfoil, single width/single inlet-SAS type secured to a machined, ground and polished solid steel shaft. The shaft shall be coated with a rust inhibitor and shall be supported by two outboard bearings. The fan assembly shall be dynamically balanced. Bearings shall be of the self-aligning ball bearing pillow block type and shall be designed for a minimum of 200,000 hours average life. Drive shall be by means of multiple V-belts. Motors shall be heavy-duty open drip-proof, three-phase, 1800 RPM, mounted on a heavy-duty sliding base. Motor and fan assembly shall be mounted on a heavy-duty steel frame supported by springs with 1-inch deflection (2-inch deflection available). Exhaust air discharge through a non-motorized, fully-insulated gravity relief panel.

## *Propeller Exhaust Air*

Propeller exhaust fans shall each have six die- formed blades welded to a steel hub assembly. Gussets which extend three-quarters of the blade length are welded to the blades to reinforce, strengthen and prevent twisting and loss of shape under load. Each fan shall be belt-drive. Shaft bearings are pillow block type. An exhaust air non-motorized backdraft damper shall be supplied with each fan.

## *Filters*

The units shall be provided with filters installed in a galvanized steel filter rack. The filters shall be 4-inch 30% efficiency (ASHRAE 52-76 Standards) throwaway type. The filters shall be provided with easy access for insertion and removal.

## *Unit Main Disconnect Switch*

The unit shall be furnished with a molded case switch (non-automatic circuit breaker) to disconnect the power supply. The design shall incorporate a switch handle to permit unit disconnect without opening the control panel doors.

## Main Control Panel

The main control panel shall have an access door for direct access to the controls. The panel shall be equivalent to NEMA type 3R (rainproof) and shall contain a single, externally operated, molded case switch (non-automatic circuit breaker) suitable for copper wire up to and including 3-inch conduit. Wire and conduit entrance shall be inside of unit curbing. The main control panel shall include the following:

1. A power terminal block.
2. A power transformer with 115-Volt secondary transformer and 115-Volt circuit breakers.
3. A 24-Volt control transformer and circuit breakers.
4. Necessary relays.
5. A 115-Volt terminal strip.
6. A 24-Volt terminal strip which shall contain wired terminals for all controls, numbered in accordance with the wiring diagram.
7. An isolated 24-Volt field wiring terminal strip.
8. An electric print pocket which in addition to the electric print shall contain a pre-startup form, a startup form and maintenance instructions.

The above components shall be in addition to electrical components associated with other sections, which shall be incorporated in the main control panel to facilitate maintenance and trouble-shooting. All components shall be identified with name tags and wired in accordance with National Electric Code.

## Temperature SST Controls, Variable Air Volume (VAV) Cooling

Each unit shall be furnished complete with all operational controls. All controls in the basic control package shall be factory installed and wired. The control system shall be a solid state integrated system consisting of a master control sequencer, a discharge air temperature sensor, and a 24-Volt control transformer. The discharge air sensor shall have a platinum resistance-type element which shall sense average discharge air temperature and send a ramp signal to the master control sequencer. The master control sequencer shall accept the signal and initiate stages cooling in proper sequence to maintain a constant discharge air temperature. The master control sequencer shall provide a variable time delay between cooling stages to prevent compressor short cycling.

The economizer control system shall include a modulating spring return, outside air/return air damper actuators, and an enthalpy/sensible changeover control. The enthalpy/sensible changeover control shall determine the capability of the outdoor air to provide free cooling. On a call for cooling, the master control sequencer shall modulate the economizer damper actuators to maintain the discharge air temperature at the effective set point. If this does not meet the space demand, the discharge air sensor shall cause the master control sequencer to energize the required amount of mechanical cooling. The economizer cycle shall allow only enough outside air to maintain the discharge air conditions. If the ambient conditions rise above the enthalpy/sensible changeover control set point, the economizer shall return to the minimum outside air position. The economizer shall have a minimum position potentiometer mounted in the economizer damper actuator.

## Remote Status Panel

A remote light indication room panel shall be supplied with each unit. The remote panel shall be supplied complete with the following:

1. Fan-on light
2. Cooling-on light
3. High head pressure failure light
4. Low suction pressure failure light
5. Oil pressure failure light
6. Service (change out) filter light

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# Woods Practical Guide to Fan Engineering



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Published by
WOODS OF COLCHESTER LIMITED
Founded 1909
An associate Company of the General Electric Co. Ltd. of England

First published July 1952
Second impression November 1952
Third impression September 1954
Fourth impression February 1956
Fifth impression June 1957
Sixth impression October 1957

SECOND EDITION
June 1960
Second impression March 1961
Third impression August 1964



MADE AND PRINTED IN ENGLAND BY
BENHAM AND COMPANY LIMITED
COLCHESTER

SECTION 15

# Fans

THE DEFINITION of a fan is a machine which propels air continuously by aerodynamic action. Piston-type compressors and positive displacement machines in general are not classed as fans. There are three basic types of fans: centrifugal, propeller, and axial flow. The last two are sometimes regarded as a single group, but the differences in their design and characteristics are such that separate classification is warranted.

Desk and ceiling fans are actually of a propeller type, but are not generally included in that category. They do not come into the field of fan engineering proper and are not dealt with in this publication.

## CENTRIFUGAL FANS

The centrifugal fan comprises an impeller which rotates in a casing shaped like a scroll as illustrated in fig. 15-1. The impeller has a number of blades or plates around its periphery, similar to a water wheel or the paddle wheel of some shallow draught river steamers. The casing has an inlet on the axis of the wheel and an outlet at right-angles to it as shown in fig. 15-2. When the impeller rotates the blades at its periphery throw off air centrifugally in a direction following the rotation. The air thrown off into the scroll is forced out of the outlet as more and more leaves the blades. At the same time air is sucked into the inlet to replace that which is discharged. The air enters axially, turns at right-angles through the blades, and is discharged radially. The purpose of the scroll is to convert the high velocity pressure at the blade tips into static pressure.

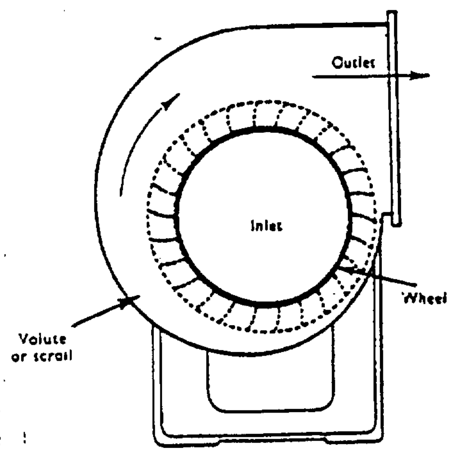


Fig. 15-1. General arrangement of centrifugal fan

## FAN PERFORMANCE

Fans are selected to give a certain quantity of air against a certain pressure and their performance must be defined largely by these two factors. Although designed for optimum performance at a given duty, a fan is capable of working quite reasonably over a range of pressures and volumes, and its performance is more completely defined by a table, or graph of pressure and volume flow of air. This is known as the "characteristic" of the fan. Fig. 15–24 shows a typical pressure-volume characteristic of a 24in. diameter Aerofoil fan with a blade angle of 24° running

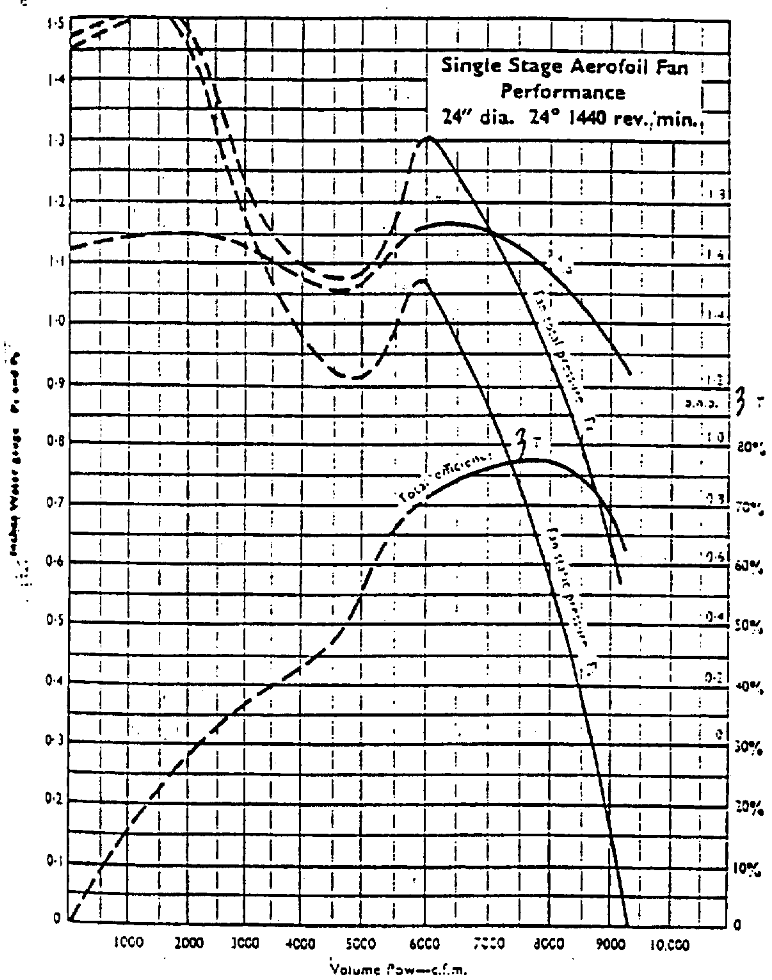


Fig. 15–24. Pressure-volume characteristic of a single-stage axial flow fan

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at 1440 rev/min, with additional curves of b.h.p. and fan total efficiency to complete the information. The efficiency curve shown is based on fan total pressure as this is a measure of the total work done on the air.

The relationship between volume, pressure, power and efficiency may conveniently be stated as below, using the following symbols:

| | | |
|---|---|---|
| Q | ... | Volume flow of air in unit time—c.f.m. |
| $P_T$ | ... | Fan total pressure—in. w.g. |
| $P_S$ | ... | Fan static pressure—in. w.g. |
| b.h.p. | ... | horse-power absorbed by fan. |
| $\eta_S$ | ... | Fan static efficiency. |
| $\eta_T$ | ... | Fan total efficiency. |

b.h.p. absorbed by fan

$$= \frac{\text{Volume flow of air, Q c.f.m.} \times \text{fan total pressure, } P_T \text{ in. w.g.}}{6350 \times \text{fan total efficiency}}$$

$$= \frac{\text{Volume flow of air, Q c.f.m.} \times \text{fan static pressure, } P_S \text{ in. w.g.}}{6350 \times \text{fan static efficiency}}$$

from which may be derived the relationship

$$\frac{\text{fan static efficiency } \eta_S}{\text{fan total efficiency } \eta_T} = \frac{\text{fan static pressure } P_S}{\text{fan total pressure } P_T}$$

for the same volume flow of air.

**Fan laws**

Fans are usually made in ranges of size and speed and if, in a given range, each one is identical in all other respects than size to the others, the fans are said to be "geometrically similar". Certain laws govern the relative performance of these fans when working at the same point on the pressure-volume characteristic and may be stated briefly as follows:

With constant impeller size.

1. Volume flow varies directly as the speed of rotation.
2. Pressure developed varies as (speed of rotation)$^2$.
3. b.h.p. absorbed varies as (speed of rotation)$^3$.

With constant speed of rotation.

4. Volume flow varies as (impeller size)$^3$.
5. Pressure developed varies as (impeller size)$^2$.
6. b.h.p. absorbed varies as (impeller size)$^5$.

Consequently with varying speed of rotation and impeller size.

7. Volume flow varies as (speed of rotation) $\times$ (impeller size)$^3$.

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of air density $\rho$. The constant now is known as $K_S$ or $K_T$ according to whether comparison is being made on static or total pressure.

$$\therefore \text{ Static fan pressure } P_S = K_S \times \left(\frac{n}{1000}\right)^2 \times (\text{d in ft.})^2 \times \rho_S$$

$$\text{Total fan pressure } P_T = K_T \times \left(\frac{n}{1000}\right)^2 \times (\text{d in ft.})^2 \times \rho_S$$

$$\text{Similarly b.h.p.} = K_P \times \left(\frac{n}{1000}\right)^3 \times (\text{d in ft.})^5 \times \rho_S$$

$K_Q$, $K_S$ and $K_T$, and $K_P$ represent the volume flow, pressure and b.h.p. of a one ft. dia. fan running at 1000 rev/min with air at standard density. From the equations on page 138 it follows that:

$$K_P = \frac{K_Q \times K_S}{6350 \times \eta_S} \quad \text{where } \eta_S = \text{fan static efficiency}$$

$$= \frac{K_Q \times K_T}{6350 \times \eta_T} \quad \text{where } \eta_T = \text{fan total efficiency}$$

If fan performance is now plotted in terms of $K_Q$, $K_S$, $K_T$, and $K_P$ instead of volume flow, fan static, and total pressures, and b.h.p. a basis of comparison between fans of different series is readily available, the shape of the "standard" characteristic being in every way identical with that of any fan of the same series. Figs. 15–25 and 15–26 show the characteristics of a type J Aerofoil fan, one of 24in. diameter running at 1440 rev/min and the other in terms of coefficients $K_Q$ and $K_S$.

## REVERSIBILITY OF FANS

In many ventilating and air circulating systems it is desirable at some time to reverse the direction of air flow. Sometimes this is done as an emergency measure, and in some cases to prevent stagnation of air in such places as ships' cargo spaces and refrigerated spaces.

If centrifugal fans are employed reversal will entail a rather complicated system of ductwork, which provides by means of doors an alternative path for the air. Reversal of air flow from centrifugal fans is impossible by any other means, as they are essentially non-reversible.

Propeller and axial flow fans are, however, essentially reversible fans, though, depending upon the individual design, some are more effective than others. Reversal of air flow is simply achieved by reversing the direction of rotation and in the case of electrically driven fans, by means of a switch. This method may be applied to non-guide-vane single-stage fans and to contra-rotating fans, but fans with guide vanes are generally unsuited to this method of reversal.

With the usual types of propeller and axial flow fans, a reduced volume is delivered when the impeller runs in the reverse direction, and is generally from 70% to 75% for propeller and single stage fans and 65% to 70% of the forward volume for contra-rotating fans when operating on the same system of ductwork.

Where equal volume is required in both directions, special fans such as truly reversible Aerofoil fans can be constructed. These have the impeller blades assembled with aerofoil sections set alternately in opposite directions. Thus, whichever way the impeller rotates the conditions of running are the same, and therefore the same volume flow of air results.

It is obvious that some reduction in performance compared with the air delivery given by the standard design is inevitable, but this reduction is not great. For instance, by comparison with a standard Aerofoil fan of the same size and speed, a Truly Reversible Aerofoil fan will deliver about 85% of the volume against about 70% of the pressure. The total efficiency of such a fan is quite high, being 60% to 65%, compared with 70% to 78% of the comparable standard fan.

## OPERATION OF FANS IN PARALLEL

Identical fans may be operated quite satisfactorily in parallel when two such fans will deliver twice the volume of air at the same pressure as a single unit. Non-identical fans, too, may be operated in parallel, but care must be taken to select a good working position on the combined characteristic and even then maximum efficiency is unlikely to be achieved at the same time by each fan.

If, as in the case of an axial flow fan of high blade pitch angle, stalling characteristics are exhibited at high pressure, the combined unit will also

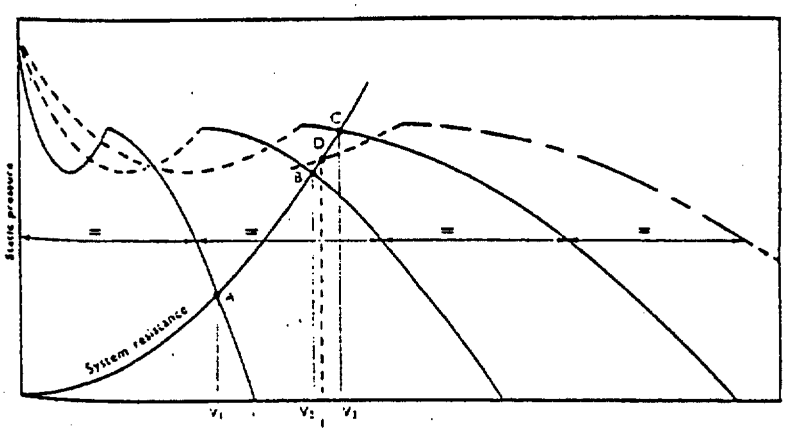


Fig. 15–27. Volume and pressure characteristics of fans in parallel

exhibit these characteristics. Consequently, care must be taken in selection of fans for parallel operation to avoid this possibility. The danger is probably greatest when it is desired to add another fan to the system, in which case, as is illustrated on page 147 by point D, the point of working on the combined characteristic may easily be changed from a perfectly satisfactory one to a very unsatisfactory one.

Two fans operating on the same system, it should be noted, do not give twice as much air as one of them would give when working alone on the system. As the resistance of the system usually increases as the (volume flow of air)$^2$, the latter settles down at some value which is less than twice the volume given by one fan. The increase in volume per extra fan decreases as the number of fans working in parallel is increased.

A form of volume control is feasible by switching off one or more units, but generally it will be necessary to provide anti-backdraught devices to prevent short circuiting of the air back through the fans not in use.

Fans are usually operated in parallel when lack of space forbids erection of a single large fan. Sometimes, too, a number of small fans may be installed at a lower capital expenditure than a single unit capable of the combined duty. Moreover, the risk of complete shut down is minimised as individual fans may be taken out of service for maintenance without closing down the system, provided shutters are available for blanking off the apertures of the shut-down fans.

## VOLUME REGULATION OF FANS

In many fan systems some control of the volume flow of air is desirable. This may be done by any one of many methods, though some methods are much more desirable than others. From the point of view of power consumption, the ideal method is to vary the speed of the fan, although in practice even this cannot be achieved without some loss of power. Fig. 15–29 gives an idea of the relative merits of the following types of volume control compared on a power consumption basis with the ideal method of speed regulation.

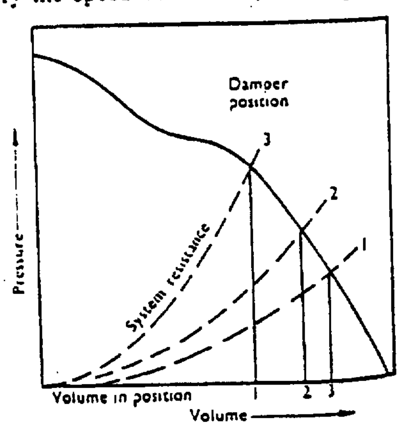


Fig. 15–28. Effect of damper control

### Damper control

This is a method very widely used as it is provided by some simple method of throttling the air flow in the system. In other words, the system resistance is varied by

frequency distribution of the main fan will be lower than that of a fan designed to supply a single 9in. × 9in. duct. The sound power level at each outlet is therefore:

$$79 - 9 - 1 - 2 = 67 \text{ dBp.}$$

**Sound absorbers**

Proprietary absorbers or silencers usually sub-divide the area available for air flow into several passages each lined with perforated sheet backed by rock-wool, glass fibre or some other sound-absorbing material. The attenuation in decibels should be quoted, preferably in octave bands of frequency so that the degree of match with the frequency distribution of the fan may be gauged. Resistance to air flow must also be considered since it is clearly unsatisfactory to absorb so much pressure (inches w.g.) that the fan speed has to be put up, thereby generating more sound and incurring additional power consumption.

Absorbers may be built to suit an installation by inserting into the duct splitters having perforated walls and packed with absorbent material. To be effective on both faces the splitter needs to be twice the thickness of the equivalent duct lining. The benefit obtained from the use of splitters lies primarily in reduction of length since the same amount of absorbent material used as a simple lining may be equally effective if the necessary length is available.

Fig. 18–9 shows some examples of lined ducts which will pass equal volumes of air for the same pressure drop, and will also provide equal noise reduction according to the formula usually employed. This may be written:

$$\text{dB} = 4{\cdot}2\, a^{1\cdot4} L\, (4A/P)$$

L = Length in direction of air flow, in.

P = Perimeter of cross-section, in.

A = Area of cross-section, sq. in.

4A/P = Diameter of equivalent circular section,
= Length of side of square section,
= Twice width of very elongated rectangular section.

$a$ is not simply the normal absorption coefficient of the particular lining employed. It is also a complex function of the shape and size of the duct and the sound frequency. Fig. 18–10 illustrates some effective values of $a^{1\cdot4}$ which have been found experimentally.

SECTION 20

# Backdraught prevention

THE EFFECT of opposing winds must be considered when fans exhaust to atmosphere through a hole in a wall. Wind blowing against a fan outlet may restrict the air output and also cause objectionable draughts through the fan aperture. For both these reasons it is advisable to protect the fan with a shutter or cowl.

There are two types of automatic shutter for preventing backdraught when the fan is switched off—louvre and butterfly. The louvre shutter is the cheaper of the two, but its suitability is somewhat limited. This type comprises metal vanes pivoted in a steel ring, as illustrated in fig. 20-1. The vanes are opened by the fan draught and they close by gravity when the fan draught stops. To prevent undue restriction of air output the vanes must open to a minimum angle of 60 degrees. This normally requires a velocity of 1000ft. to 1200ft. per minute. If the discharge velocity is less the shutter vanes will not open sufficiently and the fan output will be restricted. Louvre shutters are therefore not suitable for fans with low outlet velocities. Nor are they to be recommended for high speed fans. The reason for this is that high velocities through the shutter make the vanes rattle. Due to this they may be objectionably noisy, and in the course of time they may even disintegrate. As a general rule louvre shutters are recommended for fan output velocities between 1200ft. and 1500ft. per minute.

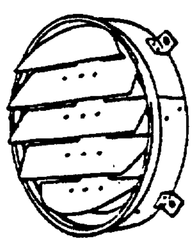

Fig. 20-1.
Louvre shutter

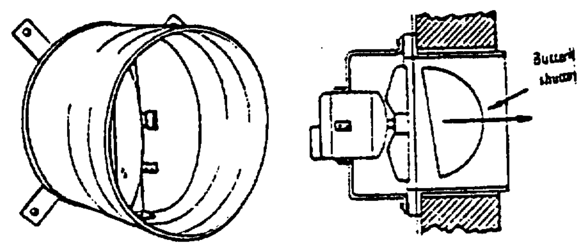

Fig. 20-2. Butterfly shutter

The butterfly shutter does not present the same limitations. This comprises a cylindrical barrel in which two semi-circular flaps are pivoted at an angle. The flaps open in the fan draught and close by gravity when the fan

# Selecting Fans, Determining Airflow for Crop Drying, Cooling, Storage

COLLEGE OF AGRICULTURAL, FOOD, AND ENVIRONMENTAL SCIENCE

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Using fans to force air having the proper temperature and relative humidity through a crop is a valuable technique for maintaining quality after harvest. The air helps maintain the moisture, temperature, and oxygen content of a crop at levels that prevent growth of harmful bacteria and fungi and excessive shrinkage.

This fact sheet provides information that will help you select new fans for crop drying, cooling, or storage facilities, or help you determine airflow delivered by existing fans. Grains and oilseeds are the primary crops discussed, but hay, potatoes, and other types of produce are also mentioned.

## Airflow Requirements

Total airflow provided by a fan is usually expressed as cubic feet of air per minute (cfm). Recommendations for drying or aerating a particular crop are given as airflow per unit of crop being served by the fan. For example, cfm per bushel (cfm/bu) is used for drying or aerating grains and oilseeds. Typical airflow recommendations are listed in Table 1. Select fans that deliver airflow within the ranges given in the table: greater airflows require larger fans and lead to greater costs, while lower airflows could result in unacceptable crop quality.

## Airflow Resistance

### Crops

When air is forced through a bulk crop, it must travel through narrow paths between individual particles. For packaged crops, air must travel through or between individual containers. Friction along air paths creates resistance to airflow. Fans must develop enough pressure to overcome this resistance and move air through the crop.

Airflow resistance and fan pressure are usually expressed in inches of water column (in. water, or in. $H_2O$). This term comes from gages called u-tube manometers that are sometimes used to measure pressure (Figure 1). You can make a u-tube manometer by fastening a clear plastic tube and a ruler to a board. Then pour some water, or water plus a small amount of antifreeze, into the tube. Since manometers are used to measure pressure relative to atmospheric pressure, leave one end of the tube open to the atmosphere. Attach the other end to the duct or plenum where you

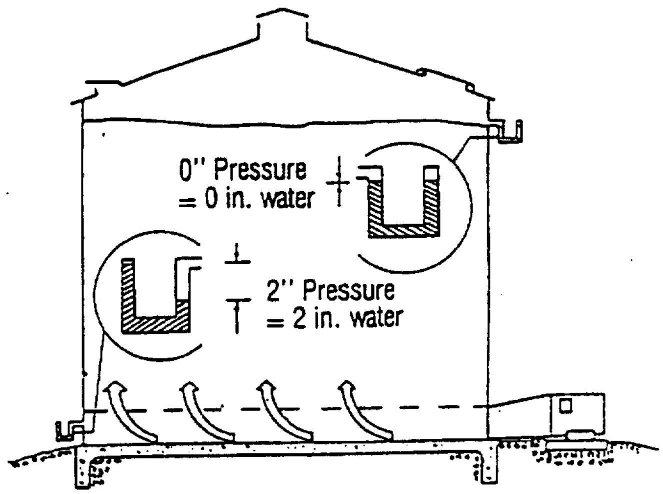


**Figure 1. Using a u-tube manometer to measure pressure in a grain bin.**

want to measure pressure. When a fan generates pressure, it forces water in the tube to move in the direction of lower pressure. The height difference of the water levels on the two sides of the tube, measured in inches, is the fan static pressure, in. water. In negative pressure or suction systems, pressure between the crop and the fan is less than atmospheric pressure and water in the manometer tube moves toward the fan. In positive pressure systems, water moves away from the fan. You can buy dial-type pressure gauges that operate on a different principle but that are calibrated to give readings in. water.

The airflow resistance of a crop and the fan pressure required to overcome it depend on how fast the air is moving and how long and narrow the paths are. For grains and oilseeds, these factors are a function of the particular crop (size and shape of seeds), crop depth, and airflow rate (cfm/bu) you're trying to provide.

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As you can see from Tables 2 through 6, at a given airflow rate, crop depth has a large effect on static pressure. Static pressure, in turn, greatly affects fan power requirements. Short, large diameter bins are recommended for natural-air grain drying because static pressure and required fan size are smaller than they would be in tall, narrow bins. Even though short bins cost more to install than tall ones that have the same grain capacity, total drying costs are less because smaller fans use less electricity.

Airflow resistance of hay, potatoes, and other produce also depends on crop depth or thickness of the layer to be ventilated and airflow rate. For packaged produce, the type of container and the way containers are stacked can also make a difference. But in most cases, airflow resistance of these crops seldom requires fan pressure greater than about 1 in. water. If better information is lacking, use 1 in. as a static pressure estimate for these crops.

### Floors and Ducts

The full perforated floors used in grain bins generally have negligible resistance to airflow. Airflow resistance of bin floors isn't significant unless open area is less than about 7%; most commercially available floors have more than 10% open area.

Air supply ducts, tunnels, and perforated air distribution ducts offer greater resistance to airflow than do full perforated floors. This resistance can be quite large if ducts are too small or too long. Use ducts that are large enough that air velocity is less than about 1500 feet per minute. (Divide duct airflow in cfm by duct cross sectional area in square feet to get velocity.) Also, try to keep duct length less than 100 ft. Unless you have better information, use 0.5 in. water as an estimate of airflow resistance for duct systems. Be aware that corrugated plastic ducts designed for air distribution have only 1 to 3% open area, and ordinary plastic tile designed for field drainage has less than 1% open area. Because plastic ducts have so little area for air exit, their airflow resistance can exceed 0.5 in. water.

### Air inlet and exhaust openings

When outdoor air is used to ventilate a bin or building, you need to provide adequately-sized openings for air to move in and out of the structure. If openings are too small, they restrict airflow and increase fan pressure requirements. Provide at least one square foot of inlet area per 1000 cfm and an equal exhaust area, and make sure these vents or doors are open anytime the fan is operating.

## Fan Performance

Because of the way fan impellers (blades or rotors) are designed, the amount of air they can move decreases as the pressure they are working against increases. The airflow vs. pressure information for a particular fan is called the fan performance data. Performance depends on the size, shape, and speed of the impeller, and the size of the motor driving it. Performance differs widely among brands and models, even for fans with the same size motor.

Access to fan performance data is essential for selecting fans and for determining airflow provided by existing fans. Most manufacturers sell fans that have been tested using procedures specified by the Air Movement and Control Association International, Inc. (AMCA). The manufacturers can provide you with performance data in the form of tables or graphs. Avoid fans for which AMCA data is not available. Table 7 is an example of the type of data you need. Figure 2 is a graphical presentation of the data for two fans from Table 7 that have the same size motor. Note how much performance of the two fans differs.

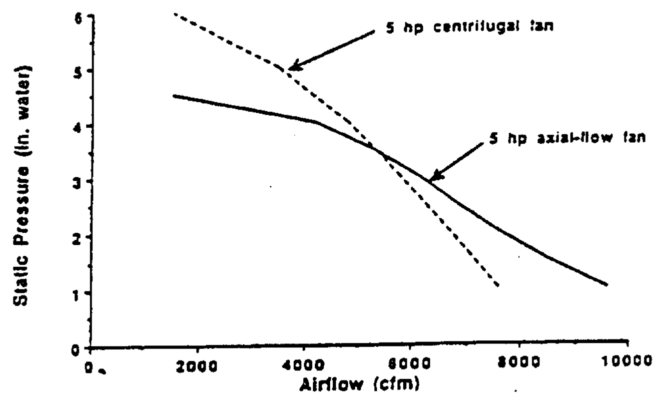


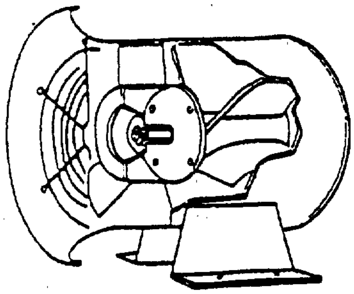

**Figure 2. Fan performance data for MES Fans #7 and #10 from Table 7.**

### Fan Types

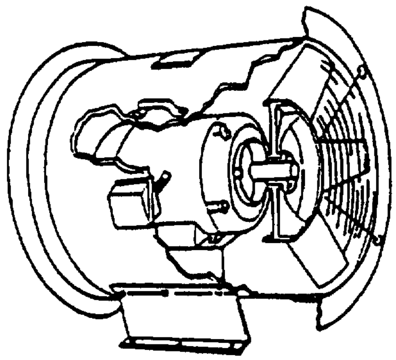
Most fans can be categorized as either axial-flow or centrifugal (see Figure 3). Axial-flow fans are sometimes called propeller fans, although that's really just one type of axial-flow fan. Air moves in a straight line through axial-flow fans parallel to the axis or impeller shaft. The impeller has a number of blades attached to a central hub.

Centrifugal fans are sometimes called blowers or squirrel cage fans. The impeller is a wheel that consists of two rings with a number of blades attached between them. Air enters one or both ends of the impeller parallel to the shaft and exits one side perpendicular to the shaft. The blades can be straight, slanted in the direction of airflow (forward-curved), or slanted opposite the airflow direction (backward-curved or backward-inclined).

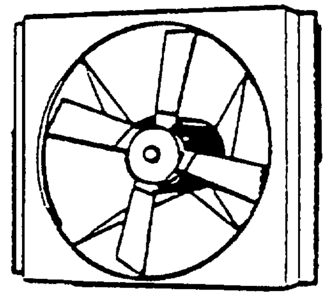
AXIAL-FLOW FANS



Vane-axial



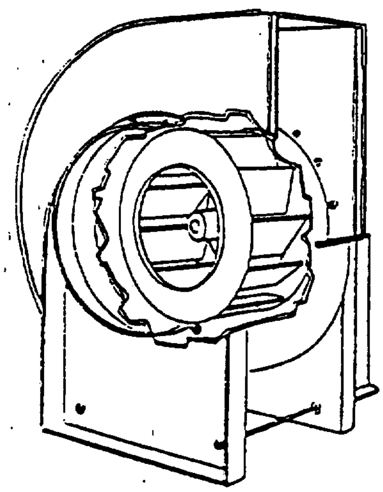
Tube-axial



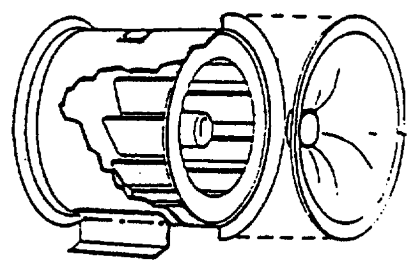
Propeller

**Figure 3. Types of fans used for ventilating crops.**

CENTRIFUGAL FANS



Backward-inclined centrifugal



In-line centrifugal

**Propeller Fans (panel fans)**

These are axial-flow type fans that have from two to about seven long blades attached to a small hub. Fan diameter is usually large relative to the fan's length or thickness. Some propeller fans are called panel fans and are designed for mounting in a wall or plenum divider. Some are belt-driven and some have the impeller hub attached directly to the motor shaft (direct-driven).

Propeller fans normally can't generate more than about 2 in. water pressure. They are most commonly used for potato ventilation, forced-air produce cooling, hay drying, exhausting air from attics or overhead spaces, or general air circulation. They are seldom used for grain drying or aeration.

**Tube-axial, vane-axial**

These axial-flow fans have a barrel-shaped housing and an impeller that has a large hub with a number of short blades attached to it. They are generally direct-driven and the motor is cooled by the airstream. In positive pressure systems, the air stream captures the waste heat given off by the motor. Vane-axial fans have guide vanes inside the fan housing to help reduce air turbulence.

Tube-axial and vane-axial fans are the most common types used for grain drying and aeration. They are relatively inexpensive and fairly efficient when static pressure is less than about 4 in. water. The main disadvantage of these fans is that they are very noisy.

**Centrifugal**

The centrifugal fans used for crop drying and storage generally have backward-curved or backward-inclined blades. They are expensive, but are also quiet and are usually the most efficient type of fan when static pressure is greater than about 4 in. water. The motor on centrifugal fans is normally outside the air stream; you need to install a special housing around the motor if you want to capture the heat it gives off.

Forced-air heating and ventilating systems often use centrifugal fans that have forward-curved blades. Motors on these fans can be overloaded and burn out when the fans are operated outside certain pressure ranges. This characteristic makes them unsuitable for many crop drying and storage applications.

**In-line centrifugal**

These fans have axial airflow, but use a centrifugal-type impeller. Price and operating characteristics are between those of backward-inclined centrifugal and tube-axial fans.

## Multiple Fans

It is sometimes necessary or desirable to install more than one fan to provide air to a common plenum or supply manifold for a duct system. Fans can be arranged in parallel or series (Figure 4). Reasons for using multiple fans include:

- Total airflow, pressure, or power requirements exceed the capabilities of the largest fan available from your dealer.
- The starting current for a single large fan motor is greater than the electrical system can handle. The maximum starting current is lower if several small fans are started one at a time.
- When multiple fans are installed, you have the option of turning some of the fans off and operating with a lower airflow when conditions allow.
- Air distribution is sometimes more uniform when several small fans are used in place of one large one.

### Parallel

Parallel arrangement means fans are installed side-by-side or at several points along a manifold or plenum. The most common applications are where total airflow requirement is large, but pressure is moderate. When fans are installed in parallel, they all face the same pressure. Total airflow is estimated by adding the airflow provided by each fan at the expected pressure.

### Series

Series arrangement, where fans are fastened in line or end-to-end, is not used very often. When it is used, it generally involves tube-axial or vane-axial fans in situations where pressure is relatively high, such as in deep grain bins. Series arrangement is seldom used with centrifugal fans and seldom are more than two axial-flow fans connected in series. When fans are arranged in series, each fan handles the same airflow. Total pressure is estimated by adding the pressure developed by each fan at the expected airflow.

## Determining Air Flow Provided by Existing Fans

Knowledge of the airflow that a fan is providing allows you to estimate the time it will take to dry or cool a crop. This in turn, helps you determine whether steps need to be taken to prevent unacceptable quality loss before the task is completed.

The first step in determining airflow is to measure static pressure in the duct or plenum between the fan and the crop (Figure 1). Drill a small hole (1/8 in. should be adequate) in the wall of the duct or plenum and press a tube from one side of a pressure gauge or u-tube manometer against the hole. Then, take the pressure reading and use its absolute value (this means assume the reading is positive even if it's a negative pressure system) to determine the airflow. Use the AMCA performance data for that model fan at that pressure. To get airflow rate (cfm/bu, for example), divide the airflow from the performance table or graph by the amount of crop being served by the fan.

For example, suppose fan #4 from Table 7 is being used to dry 10 tons of hay and the static pressure reading in the duct to which the fan is attached is 1.0 in. water. The fan performance data in Table 7 shows that fan #4 provides 2775 cfm against a pressure of 1 in. Airflow per ton is 2775 cfm ÷ 10 tons = about 278 cfm/ton. This value is within the recommended range for hay drying given in Table 1.

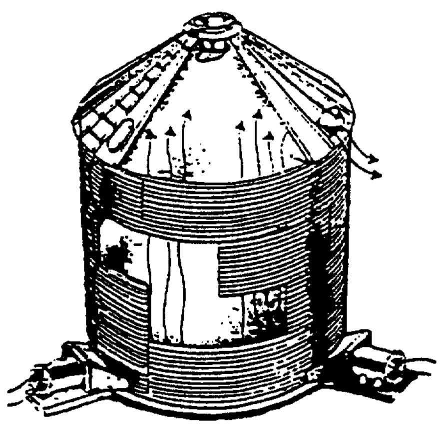
Because airflow resistance and static pressure vary with type of crop, crop depth, amount of fines present, and the way the crop is piled, you need to repeat the above procedure and determine a new airflow anytime conditions change.

## Selecting Fans

### Calculate total airflow needed

The first step in selecting a fan is to determine the total airflow it must provide. You can use the airflow rates in Table 1 as a guide. Choose an airflow rate, estimate the total quantity of crop to be served by the fan, and then multiply the airflow rate by crop quantity to get total airflow requirement.

PARALLEL



SERIES

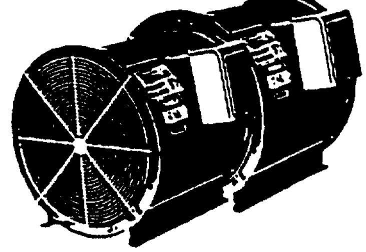


**Figure 4. Parallel and series fan arrangement.**

For example, if you want to supply 1 cfm/bu to natural-air dry corn in a 27-ft diameter by 16 ft deep bin that has a full perforated floor, calculate airflow as follows:

Bin capacity = $(\pi \div 4) \times (\text{diameter})^2 \times$ depth x 0.8 bu/cu ft

= 0.785 x 27 ft x 27 ft x 16 ft x 0.8 bu/cu ft

= 7325 bu

Total airflow = 1 cfm/bu x 7325 bu = **7325 cfm**

### Estimate static pressure

The next step in selecting a fan is to estimate the pressure the fan will be operating against. For grains and oilseeds, use the desired airflow rate and expected crop depth and read the appropriate pressure value from Tables 2 through 6. Remember to add 0.5 in. to the value from the table if air is distributed through a duct system. For hay, potatoes, or other produce, use 1 in. water as a pressure estimate unless a better number is available.

Continuing our example, Table 3 indicates that the expected pressure for 16 ft of corn and an airflow rate of 1 cfm/bu is **2.4 in. water.**

### Estimating fan power requirements

Fans are usually described by the horsepower (hp) rating of the motor used to drive the impeller. It's helpful when selecting fans to estimate the power requirement first so you know where to start looking in the manufacturer's catalog.

Fan motor size depends on the total airflow being delivered, the pressure developed, and the impeller's efficiency. Impeller efficiencies generally range from 40% to 65%. If we assume an average value of 60%, we can use the following formula to estimate the fan power requirement.

Fan power (hp) = airflow (cfm) x static pressure (in. water) ÷ 3814

In our example,
Fan power = 7325 cfm x 2.4 in. water ÷ 3814 = **4.6 hp.**

### Selecting the best fan available

Purchase cost and noise during operation can be important factors in selecting a fan, but the most critical factor is whether the fan can provide enough airflow at the expected operating pressure. Start by looking at performance data for a fan having a motor rated just under the power value you calculated. If this fan provides more than enough airflow, look at the next size smaller. If your first pick is too small, try the next size larger.

If we use the list of fans in Table 7 to select a fan for our example problem, we see that fan #7 (a 5.0-hp axial flow fan) comes closest to meeting our needs. Fans #6 and #10 wouldn't provide enough airflow at 2.4 in. water and fans #8 and #11 would provide much more airflow than is needed.

Sometimes fans produced by one manufacturer won't meet your needs and you'll have to look at another manufacturer's fans. Or, if you are having trouble finding a fan that is big enough, you might consider using several smaller fans. (See the section on multiple fans.)

### Computerized fan selection

The fan selection procedure that was just described is not too difficult, but there is an easier way to select fans for grain bins.

You can use the FANS or WINFANS (Windows version) computer programs available from the University of Minnesota Biosystems and Agricultural Engineering Department and some county Extension offices. The program is very user friendly and guides you through the fan selection process by asking some simple questions about your grain drying or storage bin. If you have access to the World Wide Web, the program can be downloaded from: www.bae.umn.edu/extens/harvest.html. The program allows you to select fans from a list of over 200 commercially available models and see if the selected models provide the desired airflow.

## Summary

Selection of proper fans and determination of actual airflow provided by existing fans are important steps in preserving quality of crops after harvest. Make sure you have fans that provide enough airflow to dry or cool crops before unacceptable quality loss occurs. Contact your local extension office for more information on selecting fans or managing crops after harvest.

**Table I. Airflow recommendations for drying, cooling, and storing crops.**

| | |
|---|---|
| Natural-air drying grains & oilseeds | 0.75 to 1.5 cfm/bu |
| Aeration of stored dry grains & oilseeds | 0.05 to 0.5 cfm/bu |
| Hay drying | 150 to 500 cfm/ton |
| Potato ventilation (airflow per hundredweight) | 0.5 to 1.5 cfm/cwt |
| Forced-air produce cooling | 1 to 10 cfm/lb |

**Table 2. Airflow resistance data for barley and oats.**
Values in the table have been multiplied by 1.5 to account for fines and packing in the bin. Add 0.5 in. water to the table values if air is distributed through a duct system.

| Grain Depth (ft) | Airflow (cfm/bu) 0.05 | 0.1 | 0.25 | 0.5 | 0.75 | 1.0 | 1.25 | 1.5 | 2.0 |
|---|---|---|---|---|---|---|---|---|---|
| | Expected static pressure (inches of water) | | | | | | | | |
| 2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| 4 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.3 | 0.5 |
| 6 | 0.1 | 0.1 | 0.1 | 0.2 | 0.4 | 0.5 | 0.7 | 0.8 | 1.1 |
| 8 | 0.1 | 0.1 | 0.2 | 0.4 | 0.7 | 0.9 | 1.2 | 1.5 | 2.1 |
| 10 | 0.1 | 0.1 | 0.3 | 0.7 | 1.1 | 1.5 | 2.0 | 2.5 | 3.6 |
| 12 | 0.1 | 0.2 | 0.5 | 1.0 | 1.6 | 2.3 | 3.0 | 3.7 | 5.4 |
| 14 | 0.1 | 0.3 | 0.7 | 1.4 | 2.2 | 3.2 | 4.2 | 5.3 | 7.8 |
| 16 | 0.2 | 0.3 | 0.9 | 1.9 | 3.0 | 4.3 | 5.7 | 7.2 | 10.6 |
| 18 | 0.2 | 0.4 | 1.1 | 2.4 | 3.9 | 5.6 | 7.5 | 9.5 | 14.1 |
| 20 | 0.3 | 0.5 | 1.4 | 3.0 | 4.9 | 7.1 | 9.5 | 12.2 | 18.1 |
| 15 | 0.4 | 0.8 | 2.2 | 4.9 | 8.2 | 11.9 | 16.1 | 20.7 | 31.1 |
| 30 | 0.6 | 1.2 | 3.2 | 7.4 | 12.4 | 18.3 | 24.8 | 32.1 | 48.7 |
| 40 | 1.0 | 2.1 | 6.0 | 14.2 | 24.4 | 36.2 | 49.8 | * | * |
| 50 | 1.6 | 3.4 | 9.9 | 23.8 | 41.4 | * | * | * | * |

* Static pressure is excessive—greater than 50 in. water.

**Table 3. Airflow resistance data for shelled corn.**
Values in the table have been multiplied by 1.5 to account for fines and packing in the bin. (If corn is stirred, which tends to decrease airflow resistance, divide table values by 1.5.) Add 0.5 in. water to the table values if air is distributed through a duct system.

| Grain Depth (ft) | Airflow (cfm/bu) 0.05 | 0.1 | 0.25 | 0.5 | 0.75 | 1.0 | 1.25 | 1.5 | 2.0 |
|---|---|---|---|---|---|---|---|---|---|
| | Expected static pressure (inches of water) | | | | | | | | |
| 2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| 4 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 |
| 6 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.3 | 0.4 | 0.6 |
| 8 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.5 | 0.6 | 0.8 | 1.2 |
| 10 | 0.1 | 0.1 | 0.2 | 0.3 | 0.5 | 0.8 | 1.1 | 1.4 | 2.0 |
| 12 | 0.1 | 0.1 | 0.2 | 0.5 | 0.8 | 1.2 | 1.6 | 2.1 | 3.2 |
| 14 | 0.1 | 0.1 | 0.3 | 0.7 | 1.2 | 1.7 | 2.3 | 3.0 | 4.6 |
| 16 | 0.1 | 0.1 | 0.4 | 0.9 | 1.6 | 2.4 | 3.2 | 4.2 | 6.4 |
| 18 | 0.1 | 0.2 | 0.5 | 1.2 | 2.1 | 3.1 | 4.3 | 5.6 | 8.7 |
| 20 | 0.1 | 0.2 | 0.7 | 1.6 | 2.7 | 4.0 | 5.6 | 7.3 | 11.3 |
| 25 | 0.2 | 0.4 | 1.1 | 2.6 | 4.6 | 7.0 | 9.7 | 12.8 | 19.9 |
| 30 | 0.3 | 0.5 | 1.6 | 4.1 | 7.2 | 11.0 | 15.3 | 20.3 | 31.9 |
| 40 | 0.5 | 1.0 | 3.1 | 8.1 | 14.6 | 22.6 | 31.9 | 42.5 | * |
| 50 | 0.7 | 1.6 | 5.3 | 14.0 | 25.6 | 39.9 | * | * | * |

*Static pressure is excessive—greater than 50 in. water.

**Table 4. Airflow resistance data for soybeans and confectionery sunflowers.**
Values in the table have been multiplied by 1.5 to account for fines and packing in the bin. Add 0.5 in. water to the table values if air is distributed through a duct system.

| Grain Depth (ft) | Airflow (cfm/bu) 0.05 | 0.1 | 0.25 | 0.5 | 0.75 | 1.0 | 1.25 | 1.5 | 2.0 |
|---|---|---|---|---|---|---|---|---|---|
| | Expected static pressure (inches of water) | | | | | | | | |
| 2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| 4 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 |
| 6 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.3 | 0.5 |
| 8 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.9 |
| 10 | 0.1 | 0.1 | 0.1 | 0.3 | 0.4 | 0.6 | 0.8 | 1.0 | 1.5 |
| 12 | 0.1 | 0.1 | 0.2 | 0.4 | 0.7 | 0.9 | 1.2 | 1.6 | 2.3 |
| 14 | 0.1 | 0.1 | 0.3 | 0.6 | 0.9 | 1.3 | 1.7 | 2.2 | 3.3 |
| 16 | 0.1 | 0.1 | 0.3 | 0.8 | 1.2 | 1.8 | 2.4 | 3.0 | 4.5 |
| 18 | 0.1 | 0.2 | 0.4 | 1.0 | 1.6 | 2.3 | 3.1 | 4.0 | 6.0 |
| 20 | 0.1 | 0.2 | 0.6 | 1.2 | 2.0 | 3.0 | 4.0 | 5.1 | 7.7 |
| 25 | 0.2 | 0.3 | 0.9 | 2.0 | 3.4 | 5.0 | 6.8 | 8.8 | 13.4 |
| 30 | 0.2 | 0.5 | 1.3 | 3.1 | 5.2 | 7.7 | 10.6 | 13.7 | 21.0 |
| 40 | 0.4 | 0.9 | 2.5 | 5.9 | 10.3 | 15.4 | 21.4 | 28.0 | 43.4 |
| 50 | 0.6 | 1.4 | 4.1 | 10.0 | 17.6 | 26.7 | 37.2 | 49.1 | * |

* Static pressure is excessive—greater than 50 in. water.

**Table 5. Airflow resistance data for oil-type sunflowers.**
Values in the table have been multiplied by 1.5 to account for fines and packing in the bin. Add 0.5 in. water to the table values if air is distributed through a duct system.

| Grain Depth (ft) | Airflow (cfm/bu) 0.05 | 0.1 | 0.25 | 0.5 | 0.75 | 1.0 | 1.25 | 1.5 | 2.0 |
|---|---|---|---|---|---|---|---|---|---|
| | Expected static pressure (inches of water) | | | | | | | | |
| 2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| 4 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.3 |
| 6 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.9 |
| 8 | 0.1 | 0.1 | 0.1 | 0.3 | 0.5 | 0.7 | 0.9 | 1.1 | 1.7 |
| 10 | 0.1 | 0.1 | 0.2 | 0.5 | 0.8 | 1.1 | 1.5 | 1.9 | 2.8 |
| 12 | 0.1 | 0.1 | 0.3 | 0.7 | 1.2 | 1.7 | 2.3 | 2.9 | 4.4 |
| 14 | 0.1 | 0.2 | 0.5 | 1.0 | 1.7 | 2.4 | 3.3 | 4.2 | 6.4 |
| 16 | 0.1 | 0.2 | 0.6 | 1.4 | 2.3 | 3.3 | 4.5 | 5.8 | 8.8 |
| 18 | 0.1 | 0.3 | 0.8 | 1.8 | 3.0 | 4.4 | 6.0 | 7.8 | 11.8 |
| 20 | 0.2 | 0.3 | 1.0 | 2.3 | 3.8 | 5.6 | 7.7 | 10.0 | 15.3 |
| 25 | 0.3 | 0.6 | 1.6 | 3.7 | 6.5 | 9.7 | 13.3 | 17.4 | 26.9 |
| 30 | 0.4 | 0.8 | 2.4 | 5.7 | 10.0 | 15.1 | 20.9 | 27.5 | 42.7 |
| 40 | 0.7 | 1.5 | 4.5 | 11.3 | 20.1 | 30.7 | 43.0 | * | * |
| 50 | 1.1 | 2.4 | 7.5 | 19.3 | 34.8 | * | * | * | * |

* Static pressure is excessive—greater than 50 in. water.

**Table 6. Airflow resistance data for wheat and sorghum.**
Values in the table have been multiplied by 1.3 for wheat and 1.5 for sorghum to account for fines and packing in the bin. Add 0.5 in. water to the table values if air is distributed through a duct system.

| Grain Depth (ft) | Airflow (cfm/bu) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0.05 | 0.1 | 0.25 | 0.5 | 0.75 | 1.0 | 1.25 | 1.5 | 2.0 |
| | Expected static pressure (inches of water) | | | | | | | | |
| 2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 |
| 4 | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 0.3 | 0.4 | 0.5 | 0.7 |
| 6 | 0.1 | 0.1 | 0.2 | 0.4 | 0.6 | 0.8 | 1.0 | 1.2 | 1.7 |
| 8 | 0.1 | 0.1 | 0.3 | 0.7 | 1.1 | 1.5 | 1.9 | 2.3 | 3.2 |
| 10 | 0.1 | 0.2 | 0.5 | 1.1 | 1.7 | 2.3 | 3.0 | 3.7 | 5.3 |
| 12 | 0.1 | 0.3 | 0.8 | 1.6 | 2.5 | 3.4 | 4.5 | 5.6 | 7.9 |
| 14 | 0.2 | 0.4 | 1.0 | 2.2 | 3.4 | 4.8 | 6.3 | 7.8 | 11.3 |
| 16 | 0.3 | 0.5 | 1.4 | 2.9 | 4.6 | 6.4 | 8.4 | 10.6 | 15.3 |
| 18 | 0.3 | 0.7 | 1.7 | 3.7 | 5.9 | 8.3 | 11.0 | 13.8 | 20.0 |
| 20 | 0.4 | 0.8 | 2.2 | 4.7 | 7.5 | 10.5 | 13.9 | 17.6 | 25.6 |
| 25 | 0.6 | 1.3 | 3.4 | 7.5 | 12.2 | 17.4 | 23.1 | 29.4 | 43.3 |
| 30 | 0.9 | 1.9 | 5.1 | 11.2 | 18.3 | 26.3 | 35.3 | 45.0 | * |
| 40 | 1.7 | 3.4 | 9.3 | 21.1 | 35.1 | * | * | * | * |
| 50 | 2.6 | 5.4 | 15.0 | 34.8 | * | * | * | * | * |

* Static pressure is excessive—greater than 50 in. water.

**Table 7. Example of fan performance data.**
This data is provided as an illustration only; these fans are not commercially available.

| Fan # | Hp | Cubic feet per minute (cfm) at indicated static pressure (inches of water) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 |
| Fans 1 through 9 are axial-flow fans | | | | | | | | | | | | | | |
| 1 | 0.33 | 1,435 | 620 | 290 | | | | | | | | | | |
| 2 | 0.5 | 1,880 | 960 | 800 | 620 | 380 | | | | | | | | |
| 3 | 0.75 | 1,690 | 1,460 | 1,170 | 780 | | | | | | | | | |
| 4 | 1.0 | 2,775 | 2,500 | 2,075 | 1,150 | 775 | 500 | 260 | | | | | | |
| 5 | 1.5 | 3,675 | 3,475 | 3,275 | 3,000 | 2,425 | 1,700 | 1,375 | | | | | | |
| 6 | 3.0 | 6,400 | 5,700 | 5,200 | 4,500 | 3,700 | 2,900 | 2,200 | | | | | | |
| 7 | 5.0 | 9,600 | 8,550 | 7,600 | 6,800 | 6,150 | 5,300 | 4,200 | 1,550 | | | | | |
| 8 | 7.5 | 13,400 | 12,500 | 11,500 | 10,400 | 9,000 | 7,500 | 6,200 | 4,450 | 2,250 | 1,350 | 650 | | |
| 9 | 10.0 | 15,700 | 15,000 | 14,200 | 13,400 | 12,600 | 11,600 | 10,500 | | | | | | |
| Fans 10 through 14 are centrifugal fans | | | | | | | | | | | | | | |
| 10 | 5.0 | 7,600 | | 6,700 | | 5,800 | | 4,800 | | 3,500 | | 1,500 | | |
| 11 | 7.5 | 9,600 | | 8,900 | | 8,000 | | 7,200 | | 6,100 | | 5,000 | | |
| 12 | 10.0 | 13,450 | | 12,720 | | 11,960 | | 11,120 | | 10,180 | | 9,040 | | 7,450 |
| 13 | 15.0 | 16,000 | | 15,100 | | 14,200 | | 13,100 | | 11,800 | | 10,000 | | |
| 14 | 20.0 | 21,725 | | 20,430 | | 19,140 | | 17,750 | | 16,140 | | 14,120 | | 11,360 |

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FO-5716-C
Revised 1999

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